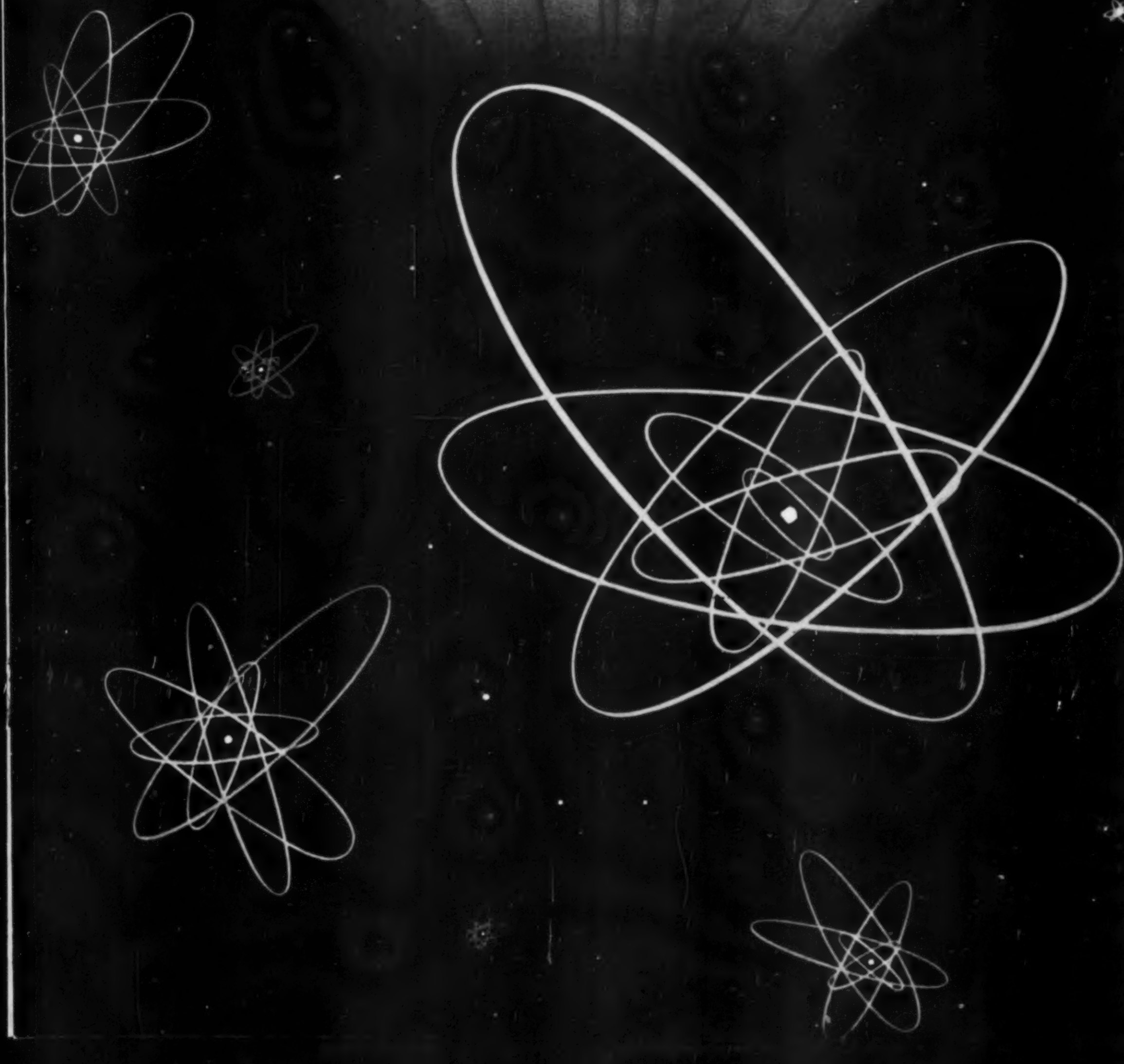
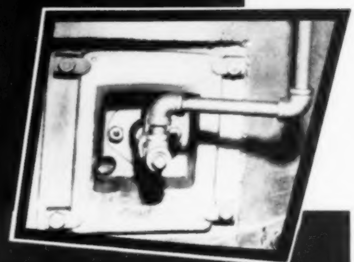
METAL PROGRESS





Above: *'Surface' Direct Fired Rotary Hearth Furnace showing charge and discharge doors.*

Right: *'Surface' High Pressure Automatic Proportioning Burners located in furnace wall, fire above and below the work, and provide flexibility in operation. This is one of fifty 'Surface' burner types available for furnace and heating applications.*

double duty

THIS VERSATILE DIRECT FIRED ROTARY HEARTH FURNACE HANDLES TWO IMPORTANT JOBS:

Number 1
NORMALIZES STARTER RING GEARS

Number 2
REHEATS FOR RESTRIKING OPERATION

● After roll and butt weld operations, starter ring gear blanks are stacked 10-high for normalizing at 1600°F. in this 'Surface' direct fired rotary hearth furnace.

Then, during another shift, the sized and weld-tested rings are reheated to 1100°F.-1200°F. for a restriking operation.

This flexibility of operation is possible through the use of 'Surface' high pressure automatic proportioning burners located in the furnace side, firing above and below the work.

'Surface' rotary hearth furnaces are built round or square and with either radiant tube for controlled atmospheres, or direct fired systems for heating.

Write for bulletins covering applications, processes, and equipment of your particular interest. No obligation.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES •

One 100 KW, 10,000 cycle TOCCO machine does 139 different production hardening jobs at Lima-Hamilton Corp., Lima, Ohio.

with TOCCO* Induction Heating

Progressive engineers at Lima-Hamilton Corporation recently adopted TOCCO Induction Heating for the hardening of bearing areas on this slide pin used in famous Lima Power Shovels. Your part may be very different but if it has to be hardened, soldered, brazed, annealed or forged TOCCO probably can cut your costs and improve your products, too.

CUTS COSTS Formerly this pin was carburized and hardened all over by conventional heating methods. Distortion was such that each part had to be straightened and then centerless ground to close limits. Rejects often ran 25% to 30%. TOCCO heats just the bearing areas that require hardening—result, no distortion, no final grinding, no rejects and 9¢ saved on each part. Production is 410 pieces per hour.

VERSATILITY, TOO In addition to the pin shown above, Lima hardens 138 other parts ranging from small screws to large gears—all on the same TOCCO machine. Between production hardening jobs, the machine is used for brazing carbide tips on cutting tools—some 10,000 during 1948. TOCCO engineers will gladly survey your plant to determine where TOCCO can cut your costs, speed-up your production, without obligation, of course.

THE OHIO CRANKSHAFT COMPANY

JUST PUSH A BUTTON

TOCCO

Mail Coupon Today

NEW **FREE** BULLETIN

THE OHIO CRANKSHAFT CO.
Dept R-4, Cleveland 1, Ohio

Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating".

Name__________
Position__________
Company__________
Address__________
City______ Zone___ State_____

LATROBE DESEGATIZED

BRAND

HIGH SPEED STEELS

•

HIGH CARBON – HIGH CHROMIUM DIE STEELS

LATROBE DESEGATIZED* BRAND STEELS cut heat treating losses by responding advantageously to heat treating processes. This desirable response is the direct result of FULL UNIFORMITY . . . that is, steel in which the all-important carbide particles are evenly dispersed throughout. This exclusive feature of LATROBE DESEGATIZED BRAND STEELS eliminates unnecessary structural stresses: cracks, checks and warpage are radically minimized . . . more freedom in design of parts is allowed . . . . ease of machining and grinding, and increased tool and die life are resultant.

LATROBE DESEGATIZED STEELS
Setting the Pace
in Tool Steel Quality!

*Trade Mark Registered U. S. Pat. Office

LATROBE ELECTRIC STEEL COMPANY

LATROBE, PENNSYLVANIA

Write or call your nearest Latrobe Sales Engineer for the complete facts on LATROBE DESEGATIZED BRAND STEELS.
Branch Offices and Warehouses are conveniently located in principal cities.

The Chapman Valve Manufacturing Company of Indian Orchard, Mass., didn't actually put the above sign on this Micromax Control Pyrometer — but they found they can count on such service when needed. For this instrument did operate, continuously without a stop of over a few seconds — for 30,000 hours or 3.42 years, regulating the little test furnace at the extreme left of the photograph.

During the run, chart paper, ink, lubricant and dry cells were replenished — but there was no maintenance — no cleaning except an occasional whisk of the janitor's brush.

Standard Equipment Used

This record was merely an incident in the routine of Chapman's Research Dept. Engineers in that plant are constantly testing valve materials, in order to be sure that the finished valves will have proper resistance to heat, pressure, chemicals and other service conditions. In this particular case the test was to be unusually long, but not otherwise noteworthy. The engineer in charge selected a furnace, and equipped it with a Micromax Pyrometer, selected more or less at random from among the hundred-odd which Chapman has on hand for such purposes. The test was then started up.

Helps Show Test Dependability

Month-in and month-out, Micromax operated with quiet efficiency until the test was over. Then, in verifying the test, engineers unearthed the details of the pyrometer's performance. They were pleased, but not particularly surprised, for they already had full confidence in their Micromax equipment. They feel, however, that even if this run is not a record performance, nevertheless it tends to show the general dependability of all their quality-guarding tests.

You may not need such continuous service, but it's helpful to know you are using equipment of that quality. If you'd like more information about the instrument, ask Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Pa., for Catalog N-33A.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

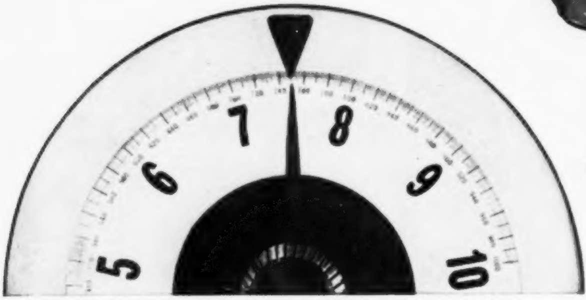
LEEDS & NORTHRUP CO.

Jrl. Ad N-420(2)

Metal Progress is published and copyrighted, 1949, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

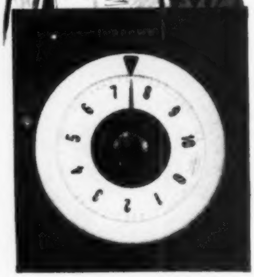
12 o'clock

AND ALL'S WELL



WITH A

Brown *ElectroniK* Indicating Controller



1. Actual temperature is always shown at the top center of a huge black-on-white scale . . . at the *12 o'clock position.*
2. When temperature is at the set point, the index is also at the *12 o'clock position.*
3. The rotating scale is almost a yard long.

All this means that you can now tell at a glance . . . even as far away as 60 feet . . . that your temperature is right.

Large control index setting knob permits easy and accurate setting of control point.

This ElectroniK Potentiometer is inexpensive in first cost and in maintenance. The few moving parts move only during temperature changes. Inside and outside, it is designed to do the job long and well . . . with unmatched speed and extreme accuracy!

Catalog 15-13 fully describes the types of control . . . electric contact and electric proportional . . . available with the ElectroniK Rotating Scale Potentiometer.

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
4503 Wayne Ave., Philadelphia 44, Pa.
Offices in principal cities of the United States, Canada and throughout the world

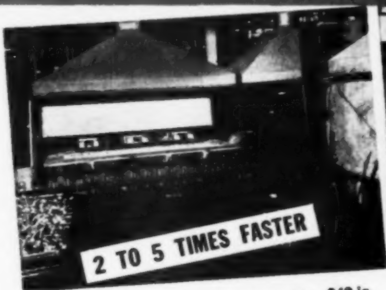
BROWN *Advanced Instrumentation* FOR METAL WORKING

Product of MINNEAPOLIS Honeywell

AJAX ELECTRIC SALT BATH FURNACES

HULTGREN

offer proved advantages like these...

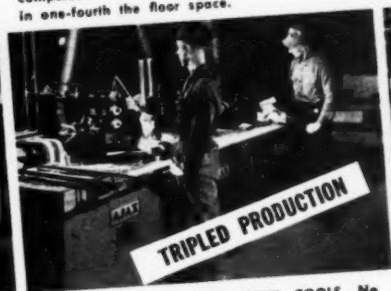


CARBURIZING automobile steering gears. .040 in. case in 2½ hours from 2 to 5 times faster than other carburizing methods.

PROCESS ANNEALING medium carbon alloy steel wire. 1200 pound charge annealed in 45 minutes compared with 12 hours previously required and in one-fourth the floor space.

NEUTRAL HARDENING silicon-manganese steel gears without decarburization. Direct savings 3½c per pound of work treated.

MARTEMPERING ball bearing races in mechanized unit eliminated 5 workers; reduced rejects from 12% to 0%. Distortion reduced from .003 in. to .001 in., eliminating need of die quenching.



HARDENING HIGH SPEED STEEL TOOLS. No decarburization or surface imperfections. Production increased 3 times over old method.

CYANIDE HARDENING ends of automotive valve pusher rods in 2 mechanized furnace lines reduced labor costs 80%.

...ON 4 HEAT TREATING APPLICATIONS OUT OF 5

Ajax Electric Salt Bath Furnaces are available in a complete range of sizes and types for:

CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING or HARDENING
STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
SOLUTION HEAT TREATMENT
DRAWING (TEMPERING)
DESCALING
CLEANING
DESANDING

Ajax Electric Salt Bath Furnaces offer tremendous advantages over conventional heat treating methods *in almost every case.* This fact is proved beyond question in well over 2,500 installations ranging from small batch type units to huge mechanized furnaces. And, by way of further proof, Ajax will gladly treat a job batch of your materials *under actual shop conditions* in the Ajax Metallurgical Laboratory. Thus you see exactly what results will be obtained, under what labor conditions and at what cost, before you buy.

Get your name on the list to receive TIPS AND TRENDS, the Ajax periodical that will keep you up to date on salt bath heat treating methods and developments. Each issue is chock-full of practical heat treating "know how" written by specialists. Available on request.

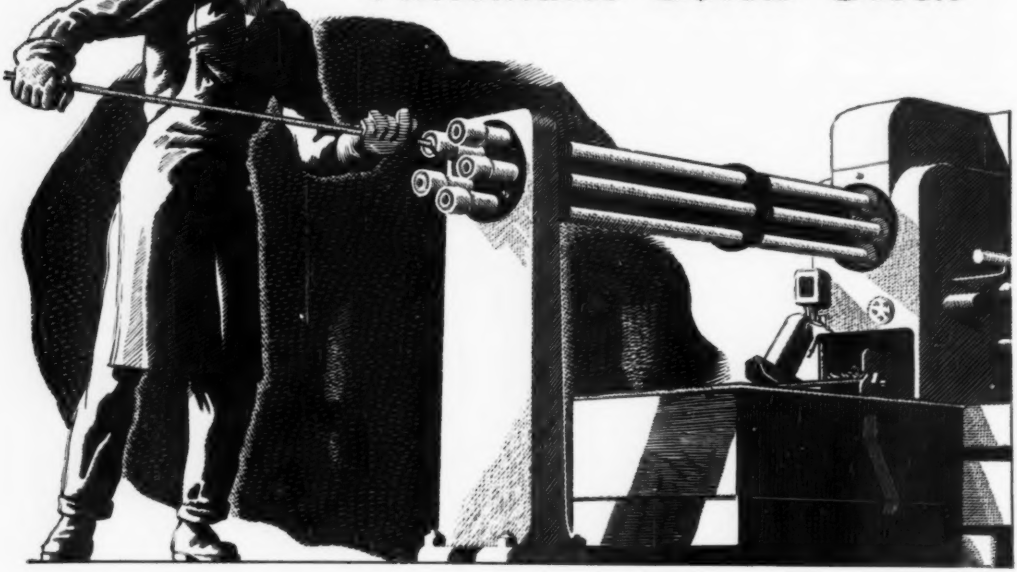
AJAX ELECTRIC COMPANY, Inc., 910 Frankford Avenue, Philadelphia 23, Pa.

THE WORLD'S LARGEST MANUFACTURERS OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY

In Canada: Canadian General Electric Co., Ltd., Toronto, Ont.

Associate Companies: Ajax Metal Co., Ajax Electric Furnace Corp., Ajax Electrothermic Corp., Ajax Engineering Corp.

COLD FINISHED BAR
Automatic Screw Stock



YOUNGSTOWN Cold Finished Carbon and Alloy Steel Bars are now being produced in a wide range of sizes and shapes, supplied either in coils or straight lengths.

Drawn to meet standard specifications, these bars have the characteristics that make them ideal for high-speed screw machine operations--uniformity of composition, toughness and strength, close tolerances in dimension, and smoothness and brightness of finish.

You'll find a Youngstown bar stock to meet almost any requirements. Tell our representative what you want and we will make every effort to serve you at once.

QUALITY · YOUNGSTOWN · SERVICE

Youngstown
COLD FINISHED CARBON AND ALLOY STEEL BARS

THE YOUNGSTOWN SHEET AND TUBE COMPANY

Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices — Youngstown 1, Ohio

Export Office-500 Fifth Avenue, New York

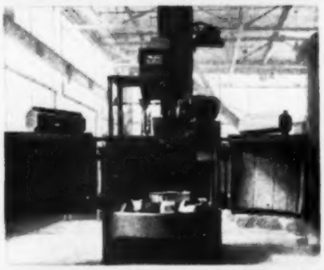
COLD FINISHED CARBON AND ALLOY BARS - SHEETS - PLATES - WIRE - TIE PLATES AND SPIKES - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - PIPE AND TUBULAR PRODUCTS - CONDUIT - BARS - RODS.

PANGBORN ROTOBLAST* Gives You All Three!

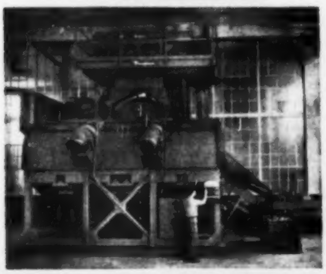
Faster . . . Better . . . Cheaper BLAST CLEANING

The Pangborn ROTOBLAST "LG" Table offers semi-continuous cleaning of work with intricate contours and multi-surfaces. The work is placed on auxiliary work tables which revolve around their own independent axes while passing through blast stream on main table orbit. Blast stream is hurled from 45° angle to clean all exposed surfaces of work. (Other types and sizes available.)

Pangborn ROTOBLAST Barrels give top efficiency in batch method cleaning. They're famous for cost-slashing Pangborn rocker barrel action which turns the work for complete cleaning on all sides. Automatic abrasive recovery mechanism saves abrasive . . . saves you money. Pangborn's automatic loading device saves time and effort in loading. Pangborn ROTOBLAST Barrels are available in a wide range of sizes for large or small foundries.



The Pangborn ROTOBLAST "Table-Room" for all general-purpose types of blast cleaning. Cleans any shape castings weighing but a few pounds, up to large castings 5 ft. by 30 in. weighing $2^1/_2$ tons. It's easy to operate. Put castings on table—close doors—turn on the blast stream. As the table rotates, castings are cleaned quickly while the operator stands outside. This machine cuts jobbing foundry cleaning costs to a par with specialty foundries.



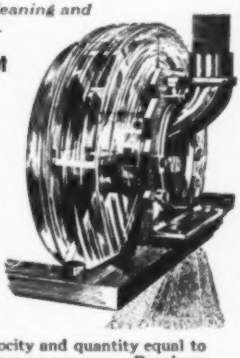
The Pangborn Continuous-Flo ROTOBLAST Barrel offers you uninterrupted, production line blast cleaning. It's the latest blast cleaning development with an unduplicated performance record. Tests show 40% savings over batch method cleaning costs. It's operated by *one* man. Castings are conveyed to feed end, cleaned by two ROTOBLAST streams, discharged ready for sorting and inspection.

CUT your cleaning costs. Speed up blast cleaning bottlenecks with Pangborn ROTOBLAST. It's the modern centrifugal method of hurling abrasive with lowest cost and highest efficiency . . . found only in Pangborn Blast Cleaning Machines.

No matter what your blast cleaning problem, Pangborn has the right ROTOBLAST Machine for your job . . . whether you clean castings, forgings, stampings or miscellaneous metal parts. Perhaps one of these models is your answer. For more information, just clip the coupon and check the bulletins you'd like to read. PANGBORN CORPORATION, 1404 Pangborn Blvd., Hagerstown, Md.

Look to Pangborn for all the latest developments in Blast Cleaning and Dust Control Equipment.

ROTOBLAST—The Secret of Top Efficiency



Pangborn's famous ROTOBLAST was developed to clean most effectively at lowest cost per hour of operation.
Cleans faster because it throws more abrasive at a larger area with greater density.
Cleans better because it produces a finer surface than old-style methods.
Cleans cheaper because it requires less horsepower to propel abrasive with velocity and quantity equal to any other method . . . uses less man power . . . Pangborn gives you top blast cleaning efficiency with the right ROTOBLAST equipment for every job.

More than 25,000 Pangborn Machines Serving Industry

Mail This Coupon Today!

PANGBORN CORPORATION
1404 Pangborn Blvd., Hagerstown, Md.

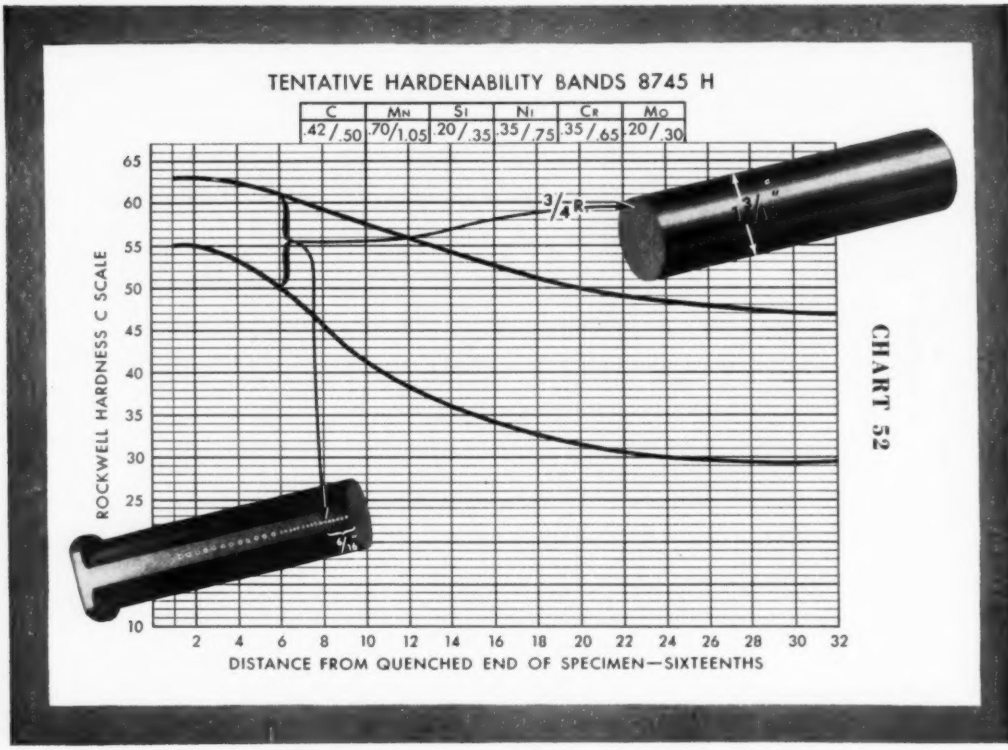
Gentlemen:
Please send me the following bulletins . . .
☐ TABLES ☐ "TABLE-ROOM" ☐ BARRELS
☐ CONTINUOUS-FLO ☐ DUST CONTROL

NAME..
COMPANY..
ADDRESS..
CITY......................ZONE......STATE..................

Pangborn

*Trademark of the Pangborn Corporation

BLAST CLEANS CHEAPER with the right equipment for every job



This hardenability chart for 8745 H shows that the Rockwell hardness at a point 6/16 in. from the hardened end of an end-quench specimen is the same as that found at the three-quarter radius of a 1-3/16-in. bar section quenched in agitated oil.

Have you considered the advantages of ordering Alloy Steels to Hardenability?

There is a definite trend toward the use of alloy "H" steels in industry. Progressive buyers of steels are specifying hardenability bands to eliminate top and bottom extremes. This provides worthwhile advantages, as top extremes in hardenability frequently cause quenching cracks and bottom extremes may mean failure to obtain the effectiveness of quench desired.

For example, a 1-3/16-in. round is needed to quench in oil to Rockwell C-50 minimum hardness at the three-quarter radius. (At this point, the hardness value is approximately equal to that of fully-tempered martensite.) Standard cooling rate curves for a mildly-agitated oil-quench show the commensurate distance from the hardened end of the end-quench test to be 6/16 in.

When this required distance is located on an established hardenability chart, such as the one reproduced above, we find that 8745 H analysis will produce 50 minimum and 61 maximum hardness. This indicates that 8745 H meets these particular requirements. The possibility of getting an 8745 type steel of lesser or greater hardenability is eliminated if the "H" steel is ordered.

Hardenability charts similar to the one shown above are now available for many standard alloy-steel grades.

Whether you order to hardenability or whether you use the conventional methods, Bethlehem metallurgists will be glad to help you with your analysis, heat-treatment and machining problems. Bethlehem is a dependable source for all of the alloy steels listed by AISI.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

ROLOCK

FABRICATED ALLOYS

An example of cost-reducing, quality-improving equipment for heat treating is illustrated by this Drop-Bottom Pit-Type Furnace Basket . . . fabricated and welded by Rolock.

When a conventional basket and load are mass quenched, the violent thermal shock is highly destructive to basket life. But this quick opening feature instantly dumps the load without immersion of basket and cuts the time interval between heat and quench to a minimum . . . assuring uniform quality, low hour-cost of basket.

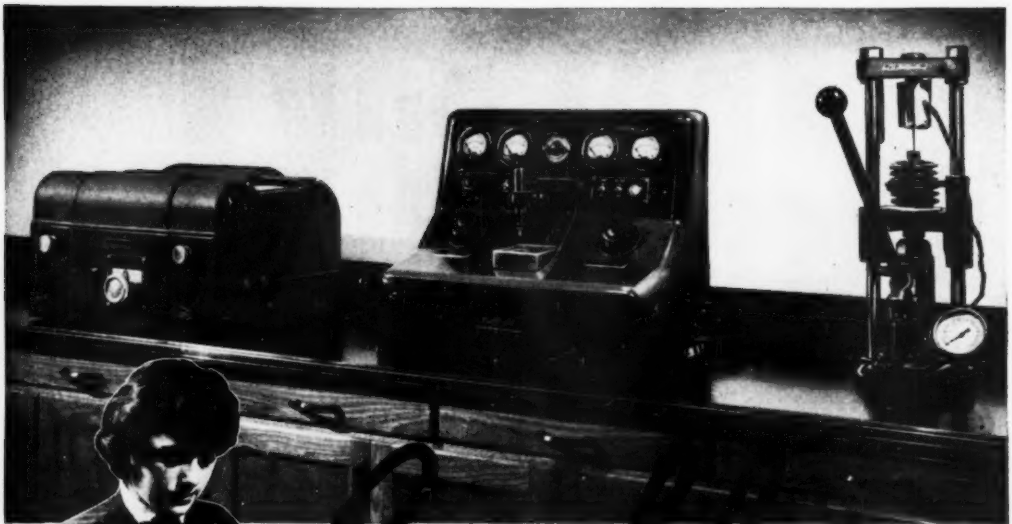
Rolock engineers can solve your specific problems . . . give you competitive advantages for today's and tomorrow's production.

We feel certain that a copy of Rolock's catalog will be of interest to you. Why not write for it today.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES

ROLOCK INC. • 1220 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost



Buehler...

METALLURGICAL LABORATORY EQUIPMENT

. . . provides the metallurgist with the most complete line of modern designed precision machines for specimen mounting and preparation available anywhere in the world. This finely made equipment has been developed through a thorough understanding of the requirements of the metallurgist and a rigid insistance on perfection in the mechanical design and construction of each item.

Everything needed for metallurgical testing from cut-off machines, moulding presses, and grinders to the mechanical or electrolytic polishers is included in the Buehler line.

In setting up complete laboratories or adding items to present equipment the metallurgists will find in the Buehler line of coordinated equipment everything needed for producing the best work, with speed and accuracy.

Operator using the new Model No. 1506 low speed polisher. Section of laboratory equipped with No. 1251 Duo Belt Sander—No. 1700 Electro Polisher—No. 1315 Press.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Write for bulletin of new equipment or information on any specific item. We invite correspondence relative to setting up complete laboratories suitable for any particular requirement.

Exclusive U. S. agents for Amsler and Chevenard Testing Machines.

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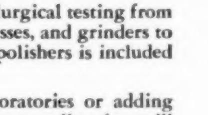


Seamless Tubing Production Line at

THE BABCOCK & WILCOX TUBE COMPANY

Demonstrates Advantages of Speed-Heating with GAS

CONTINUOUS REHEATING of seamless tubing, at production speeds integrated with piercing-mill and sizing-mill capacities, demonstrates some of the important advantages of high-speed heating with GAS.

Many types of carbon, alloy and stainless steels are used in the manufacture of seamless tubing at The Babcock & Wilcox Tube Company. During the early stages of tube formation the tubes drop in temperature before entering the sizing mill. The modern Gas-fired units in the Beaver Falls, Pennsylvania, plant perform this reheating operation at speeds up to 162 FPM for 6-inch tubing.

Another important factor is the precise temperature control which permits adjustment of production speeds to compensate for delivery from the rolling mill or the requirements of the sizing mill. In addition, the automatic controllability of GAS permits immediate adjustment of temperatures for any type of alloy tubing.

Some of the results, attributed to this high speed GAS heating system by production executives of The Babcock & Wilcox Tube Company include—

- **fuel costs for reheating reduced 63% per ton**
- **output increased over 10% per hour**
- **product improved by absolute uniformity of heating**
- **maintenance costs reduced due to equipment simplicity**

The versatility of GAS for high-speed heating has been demonstrated in all type of production operations. It's always well to keep in touch with the latest developments in effective utilization of GAS.

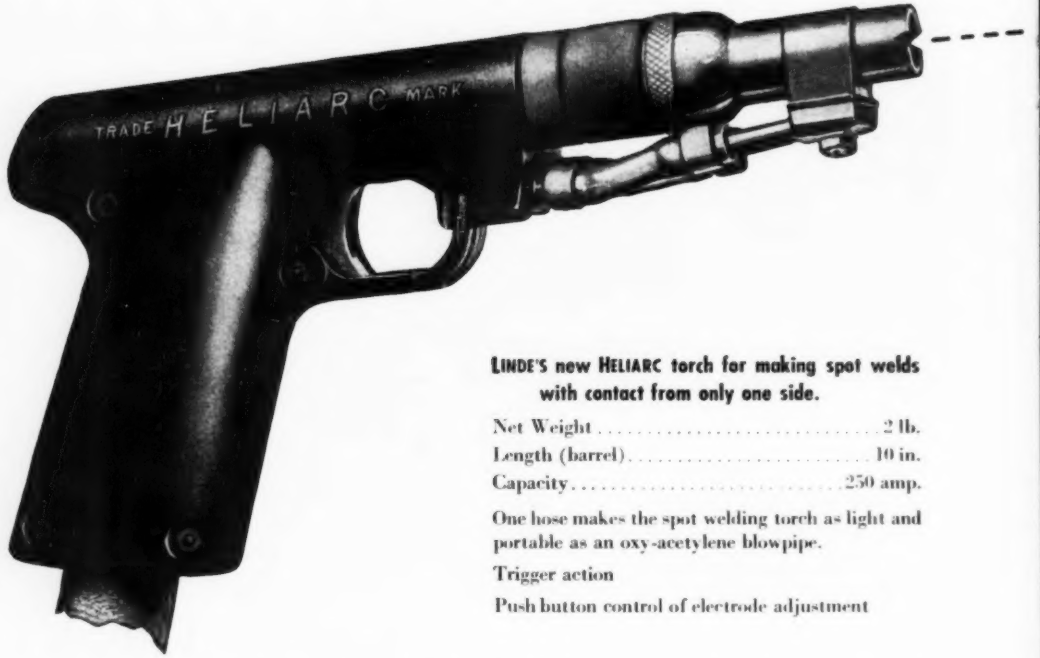
Battery of twelve continuous Gas-fired Selas heating units in which seamless tubes, on way to sizing mill, are reheated from 1300F to 1900F and above.

MORE AND MORE...
THE TREND IS TO GAS
FOR ALL INDUSTRIAL HEATING

AMERICAN GAS ASSOCIATION

420 LEXINGTON AVENUE · NEW YORK 17, NEW YORK

How would you make SPOT WELDS



LINDE'S new HELIARC torch for making spot welds with contact from only one side.

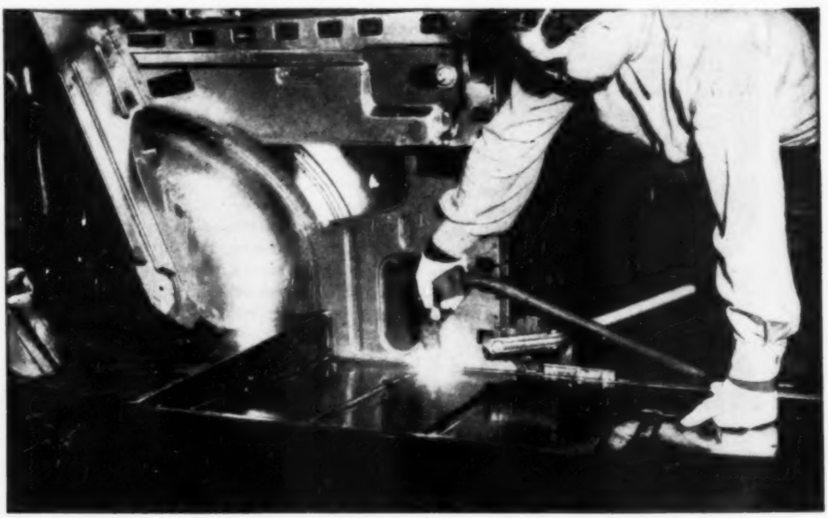
Net Weight	2 lb.
Length (barrel)	10 in.
Capacity	250 amp.

One hose makes the spot welding torch as light and portable as an oxy-acetylene blowpipe.

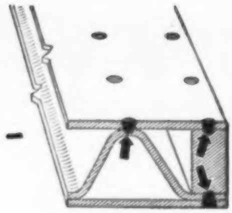
Trigger action

Push button control of electrode adjustment

With the HELIARC torch on the assembly line, you can easily make spot welds in those hard-to-get-at places. Other applications are just as easy.



IN PLACES LIKE THESE?



Full Scale

"HELIARC" TORCH SPOT WELDING can do it easily and quickly

Torch spot welding is a new use for inert-gas-shielded arc welding that fills a long-felt gap in sheet metal assembly methods. Spot welds are made by a light pistol-grip torch that requires access to the work from only one side.

Does many jobs

You can use this new HELIARC torch for many types of spot welding work. It is especially useful where the structure is large or of complicated shape because welding is done from one side and no forging pressure is required. You can spot weld ducts, tubes, containers, brackets, handles and many other assemblies. Mild steel, low alloy or stainless steel .030 to .064 in. thick are the metals that can now be welded. Not only can you join sheets of these metals in one to two seconds per spot, but you can also join a sheet of metal to underlying material of any thickness. Thus, corrosion resistant sheets can be spot welded to mild steel plate to provide cladding.

Easy to use

It's no trick to weld with the pistol-grip HELIARC HW-8 Spot Welding Torch. Just press the "muzzle" of the "gun" against the work and pull the trigger.

Low-cost power equipment is another feature of this process that makes it attractive. A regular 300 amp. welding transformer with high frequency unit is all that is needed to supply the power. Power return is by ground lead clamped to the work at any convenient location. A timer control automatically takes care of operating the accessory equipment.

Equipment is simple

Only one hose assembly connects the torch to the accessory equipment which can thus be placed out of the way to leave the entire work area free. The standard hose assembly is 25 ft. long. The hose is about an inch in diameter and contains conductors for power cable, cooling water, shielding gas, and trigger control. Electrode adjustment is easily made by push-button control located on the torch. All of these features make the spot welding torch easy and natural to use and as light and portable as an oxy-acetylene blowpipe.

The ease of use and quality of work done with HELIARC torch spot welding makes it an ideal production line tool. Contact any LINDE office for additional information about this new spot welding process.

The words "Linde" and "Heliarc" are registered trade-marks of The Linde Air Products Company.

Linde
Trade-Mark

THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation

30 E. 42nd St., New York 17, N. Y. UCC Offices in Other Principal Cities

In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto

FOR EVERY BEARING NEED!

Most white metal bearing problems can be successfully solved by using one of the Federated Big 4 Babbitts—Thermodyne, XXXX Nickel, Merit and Record.

Thermodyne and XXXX Nickel are tough, dense-grained tin-base babbitts for heavy bearing loads at high speed operation.

Merit and Record are ductile, low-cost lead-base babbitts for lighter loads at more moderate speeds.

The Federated Big 4 branded babbitts are scientifically designed to answer most white metal bearing needs, and thus to simplify your bearing problems. For special requirements, alloys of any composition can be supplied.

To order, or to obtain more information, call or write the nearest of Federated's 11 plants and 24 sales offices across the nation.

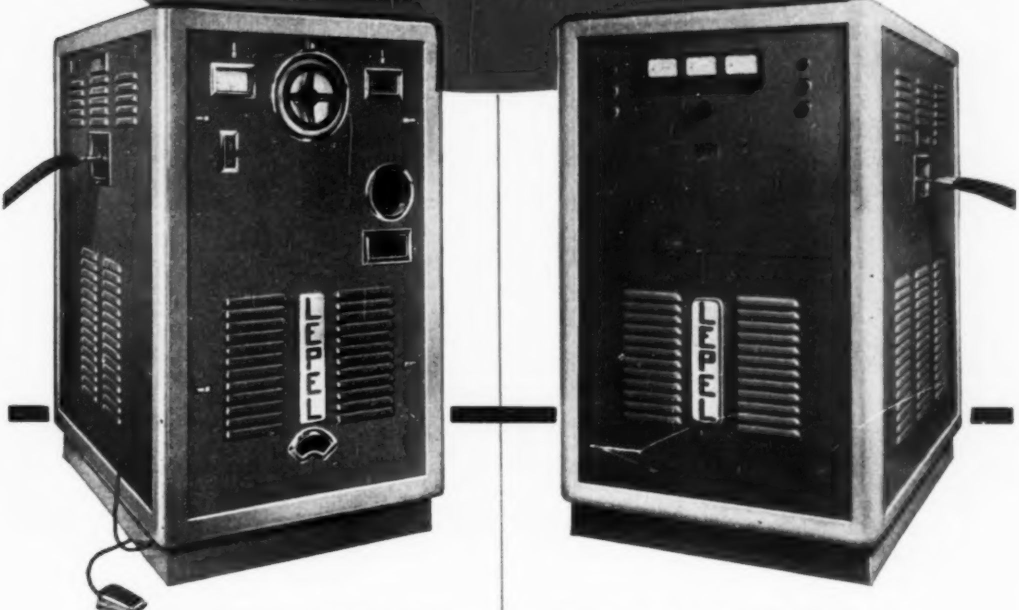
Federated also makes many other non-ferrous products, including copper-base alloys, aluminum and magnesium alloys, solders, die casting metals and fabricated lead products.

Federated — first in the non-ferrous field

Federated METALS

Division of American Smelting and Refining Company, 120 Broadway, New York 5, N.Y.

2 new units
FOR HIGH-FREQUENCY HEATING



A New SPARK-GAP UNIT and a New VACUUM-TUBE UNIT

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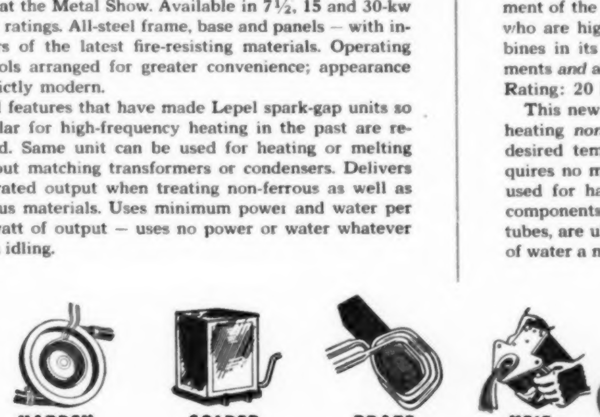

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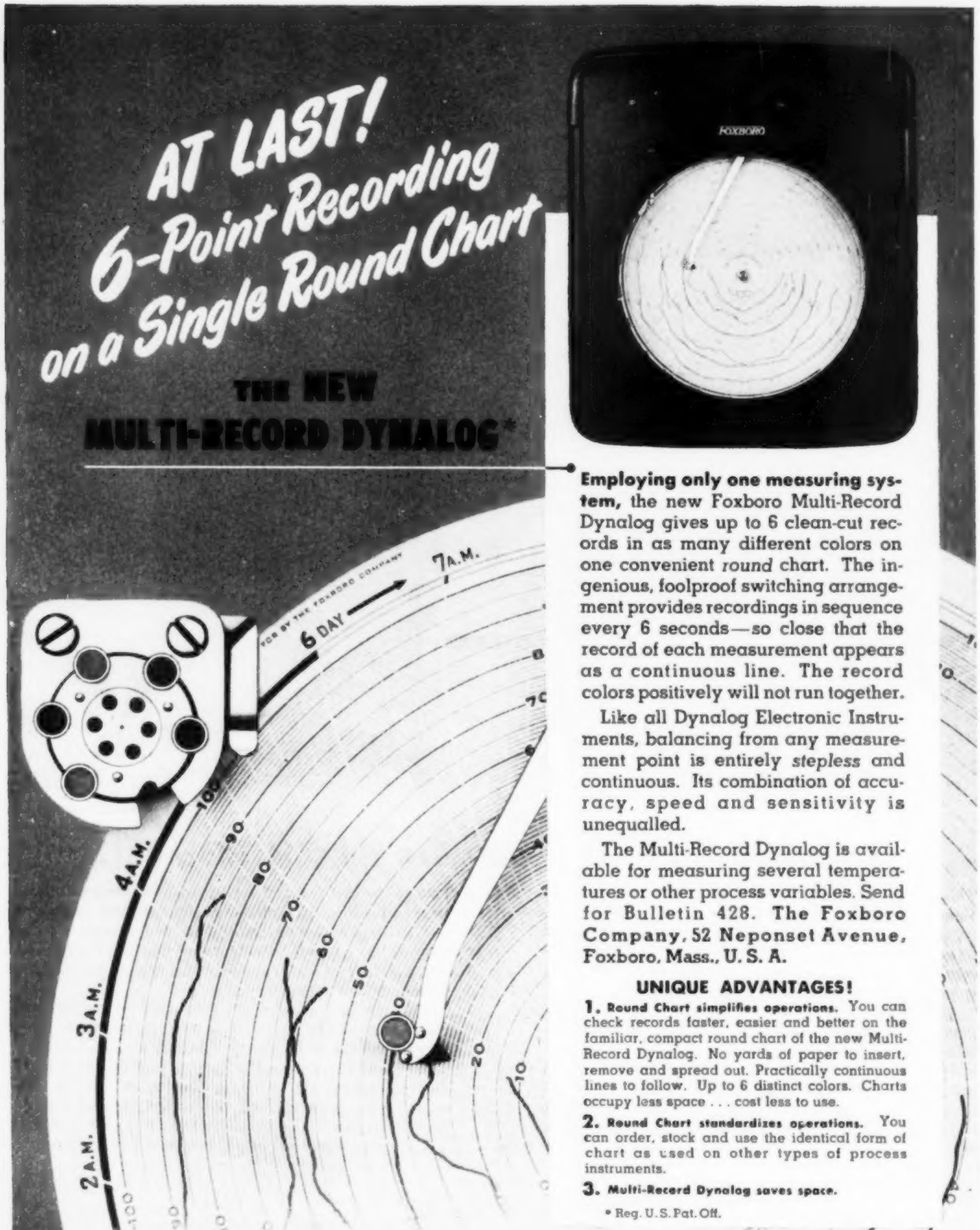
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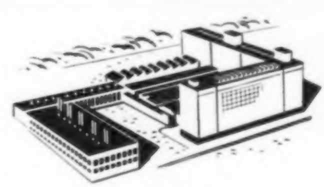

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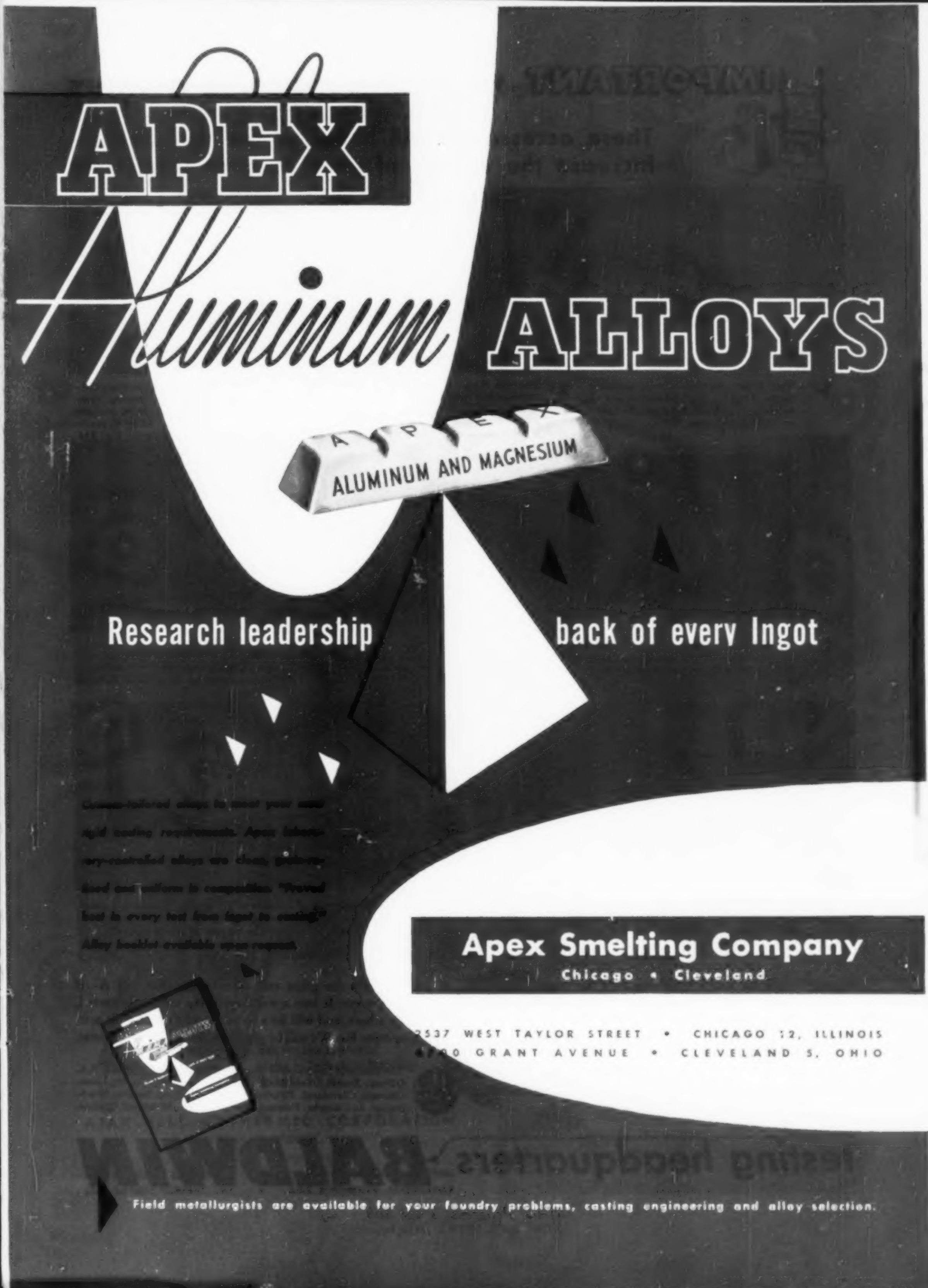
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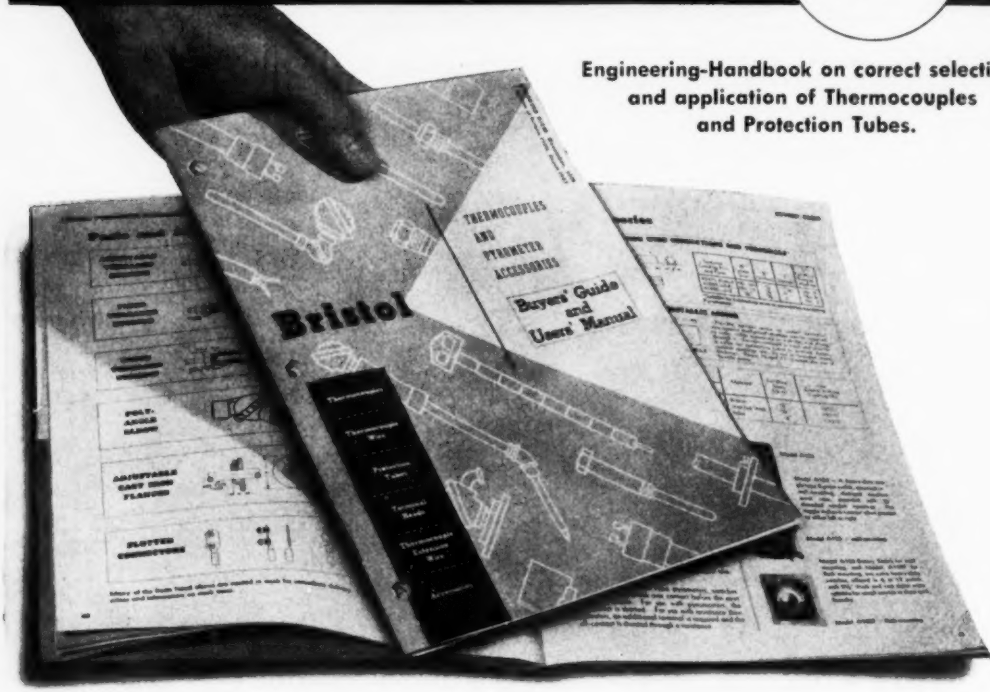

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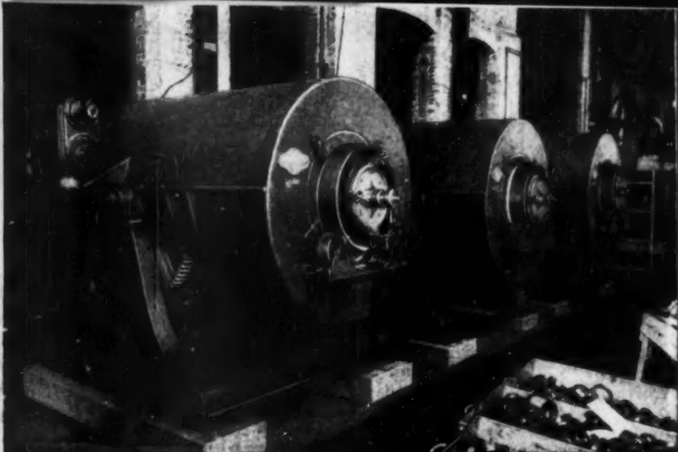

a

Furnaces shown are engineered and manufactured by American Gas Furnace Co., Elizabeth, N. J.—the pioneer builder of gas furnaces, founded 1878.

b

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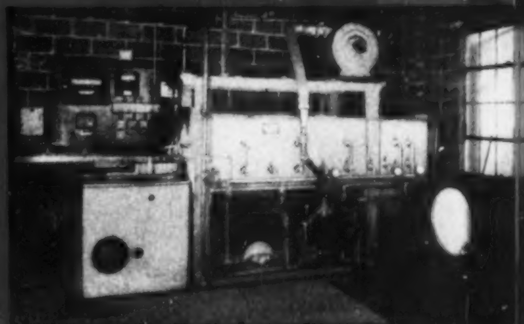

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C—Nichrome muffles in this Reciprocating Muffle Furnace, operating at temperatures between 1550° and 1700°F., have stayed on the job for as long as *12,000 hours without requiring attention* . . . gone back to work for several thousand more after receiving only minor repairs. Furnace capacity: 150 - 300 lbs. per hour. Used for carburizing, hardening and annealing

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METAL PROGRESS

Vol. 55 **April, 1949** **No. 4**

Ernest E. Thum, *Editor* Taylor Lyman, *Associate Editor*

Table of Contents

RAPID REFINING BY THE UGINE-PERRIN METHOD

By Albert M. Portevin*
Professor of Metallography
Ecole Centrale
Bessemer Medalist
Paris, France

Since it has been possible to resume pleasant relations, after the war, with American friends, I have been asked several times about the Ugine-Perrin process and its development, having written something of its origin in *Metal Progress* as early as February 1933. Consequently I feel it *apropos* to write a short article describing the present status of this process; it will serve as a collective answer to the various questions, individual and partial, and furnish a more complete picture for all.

First it might be well to quote from the article of 16 years ago:

"In order to increase the speed of reaction between the molten metal and slag, we must increase their fluidity, and the area of contacting surfaces across which the elements transfer from metal to slag and vice versa. Intimate contact of relatively small masses will avoid that slow diffusion in the very heart of the bath of steel and its covering slag which characterizes openhearth practice.

"Such accelerated operations have recently been achieved by a new process developed by R. Perrin. In some experiments at Aciéries Electriques d'Ugine, Mr. Perrin noticed that when a very fluid slag of appropriate composition is melted in a separate pot and then vigorously rabbled into the liquid metal, so as to produce an emulsion of the two, the desired reactions are extremely rapid — almost instantaneous."

Shortly before the war, Perrin succeeded in making important modifications in this process, so briefly described, and these improvements were also being applied with great success in other places besides the Ugine Electric Steel Co.'s plant in France. As an illustration, thousands of tons of alloy steel were produced at the Huta Bankova company's plant in Poland using a 50-ton basic openhearth furnace, and at the Forges et Aciéries du Nord et de l'Est in Valenciennes with a basic bessemer (Thomas) converter. These represented the beginning of industrial production of special quality steels by this process. During the occupation of France by the German army the process was dropped — everyone concerned kept quiet. It is only since the war that it has been the subject of a good deal of discussion in France.

Summary of Present Process

It would be worth while to give a brief summary of the process in its fundamental form.

The Ugine-Perrin process is based on three general principles:

First, it is fast. It seeks to refine steel rapidly by replacing the slow reactions of a slag floating on a large bath of metal by the quasi-instantaneous reaction when the metal is transferred from the

*Translated by W. M. Baldwin, Jr., research professor in metallurgy, Case Institute of Technology, Cleveland.

Fine-grained, high-quality steel (exceedingly low in sulphur, oxygen and visible inclusions) is rapidly and economically produced by using the electric furnace as a melter, slagging off, adding the required alloying elements, and pouring into a ladle containing about one tenth its weight of specially formulated slag. Adequate refining (when temperatures are correct) occurs in the few minutes required to move the receiving ladle to the teeming platform. The process has been commercial for a number of years, and greatly increased capacity is now being installed, both in France and in India.

furnace into a ladle of molten slag. This allows the greatest possible production from a furnace, since it is now principally a melter — at the price, of course, of tying up a small furnace for preparing the slag. The energy consumed in melting slag in its own furnace is small compared to the amount put into a large furnace containing metal to obtain the same fusion, plus that energy consumed during the time the mixture is held in the large furnace to allow the slag to react with the metal. Later I will give examples illustrating the rapidity of the method.

Second, the process is automatic and reproducible. It is possible to obtain results that are closely similar, heat to heat, and practically independent of the human factor. Moreover, the results will be reproducible from time to time and from one furnace to another. To develop a process that is *completely* automatic would require a closer temperature control than is available at present. Temperature obviously affects the slag-metal equilibrium as well as the course of solidification in the mold. Recent methods developed in various countries to adjust the temperature of the steel in the furnace will serve to increase the efficiency of this as well as all steelmaking processes.

Third, as far as the refining itself is concerned (deoxidation and desulphurization), the final results will be the same irrespective of the type of furnace used for the melting — whether acid or basic converter, acid or basic openhearth, acid or basic electric furnace (arc or high frequency) — provided the phosphorus, nitrogen, and hydrogen content of the metal tapped from the melting furnace is the same, since the refining action of the slag does not affect these elements. (In connection with hydrogen, there is a definite tendency for these Ugine-Perrin steels to develop fewer internal fissures or "snowflakes" during the cooling of fairly heavy sections; this can undoubtedly be accounted for by the elimination of the second slagging operation in the conventional electric furnace practice, necessary for deoxidizing and desulphurizing, and which normally permits the molten steel to absorb a substantial amount of hydrogen.)

At present, these general principles are applied commercially to three objectives: First, reduction of the phosphorus content of the steel; second, simultaneous deoxidation and desulphurization of the heat; third, production of certain ferro-alloys and high alloy steels.

I will now summarize the results obtained in the three fields.

Elimination of Phosphorus

The first objective was to lower the phosphorus content of steels produced in basic converters (approximately 0.05%) to 0.02% or less, by pouring the blown metal into a ladle containing a molten slag of iron oxide and lime.

This is easily effected, but at Northeast (as we will call the Valenciennes plant of Forges et Aciéries du Nord et de l'Est) the staff has obtained the same dephosphorization by skimming off the slag at the end of the normal blow, adding a small quantity of lime to the vessel and blowing again for a few seconds. This practice has been found to be extremely economic, and hence the Perrin process of dephosphorization has not been widely adopted by French steelmakers. Before the war, however, the staff at Ugine carried out tests for Tata Iron and Steel Co. At this plant in India, the bessemer steel (containing about 0.3% phosphorus) had been normally transferred to a large basic openhearth for dephosphorization.* Ugine's preliminary tests demonstrated that pouring such a steel into a ladle with molten slag reduces this phosphorus to less than 0.05% in about a minute! The war prevented Ugine from completing these tests, but Tata Iron and Steel Co. continued development under Yaneske's direction. Bessemer steel, in the new practice, is cast into a transfer ladle and then into a second one containing the molten slag. By this means any transfer of the acid

*The practice was described fully by B. Yaneske in *Journal* of the Iron & Steel Institute, 1927 — I, p. 181 ("The Manufacture of Steel in India by the Duplex Process").

bessemer slag into the dephosphorizing slag is avoided. The results were satisfactory and were reported in a paper by Mr. Yaneske to the Iron and Steel Institute in 1940 ("The Manufacture of Steel by the Perrin Process").

The Tata company subsequently decided to use this process in a new plant, casting the metal directly from the converter to the ladle containing the slag. This plant was built during the war, and there was no chance for consultation between the Tata and Ugine staffs. Unfortunately the shape of the converter's mouth did not prevent the acid slag from running out with the metal and mixing with the basic slag in the ladle — which, of course, was fatal.

Experiments were resumed recently and the bessemer slag was completely held back. These heats have regularly reduced the phosphorus content from 0.35% in the blown metal to 0.025% in the steel ready for teeming. The active slag weighs only 7% of the weight of the steel.

Steel Refining

The Perrin process is a powerful, rapid and automatic process for deoxidizing and desulphurizing steel.

It is well to emphasize this matter of desulphurization, since at first Perrin used an acid slag, which of course had no action on the sulphur content of the steel treated. An acid slag produced a steel with a McQuaid-Ehn grain size of 3 to 5. Since French specifications contain no requirements as to grain size, the process was quickly exploited at Ugine for the production of a specialty. Scientific studies of the basic converter at Corby, England, and the basic openhearth in America demonstrated effectively enough, however, that steel with a fine grain size (6 to 8) made under an acid slag has unsatisfactory cleanliness.

From a systematic study of inclusions made at the Ugine laboratories by Castro and myself (published in the *Journal* of the Iron and Steel Institute in 1935, 1936 and 1937) it was concluded that the best means of producing a fine-grained steel by a rapid process would be to introduce small quantities of aluminum† from the slag during mixing; specifically, it was thought this result could be obtained by reaction between a steel containing silicon and a synthetic slag high in alumina and lime. (Alumina-bearing slags are more expensive than those containing silica, but this is compensated by the fact that the spent slag is a valuable raw material for the cement industry.) These new slags, the analysis of which will run around 3% SiO_2, 43% Al_2O_3, 53% CaO, and less than 1% FeO, represent only one group of many employed in the Perrin process, but they are recommended especially where good general results are sought — that is, a combination of desulphurization, cleanliness, fine grain, and good mechanical properties.

Introduction of aluminum into the steel from the slag is shown indirectly by the fact that even without any final direct addition of aluminum, one obtains metal with a fine McQuaid-Ehn grain size. The aluminum so added by the methods employed at Ugine amounts to 0.005% or slightly more. Further, if increasing quantities of aluminum are added to a series of ingots as they are cast in the mold (a practice that is not highly favored because it ordinarily tends toward dirty steel), it is found that the cleanliness — number of visible inclusions — is not affected even in those ingots with large aluminum additions. This Ugine-Perrin method, therefore, offers a precise means of controlling the final aluminum content of the steel and the properties that depend on it.

These new slags were tried at Ugine for the first time in 1938 on a nickel-chromium steel for case hardening. Clean, fine-grained steel was obtained, and in addition it was found that the reaction between the extra silicon in the steel and the slag was such as to lower the sulphur considerably after short periods (of the order of one minute) provided the alumina and lime content of the slag was properly adjusted. These new slags were quickly adopted at Ugine and elsewhere.

Perrin likewise defined in his patents the group of conditions necessary and adequate for good desulphurization by molten slags, dealing generally with the basic slags. If I speak particularly in this article of slags with high alumina content, it is because these are the ones that give the best results from several different points of view — desulphurization, deoxidation, cleanliness, and the qualities of the finest steels.

It is perhaps worth while to describe some specific examples of desulphurized steels in view of the importance of low sulphur content on a number of quality factors. I will intentionally choose some results obtained in steel plants other than at Ugine, in Table I (p. 478), to illustrate the reproducibility of the process.

These few examples in Table I illustrate the extent of the desulphurizing action, even in the extra mild steels. At the same time the oxygen contents will be of the order of 0.002 to 0.005% with corresponding cleanliness, even in steels with a 6 to 8 grain size and whether they come from an openhearth or electric furnace. The number of

†The effect of aluminum additions on inclusions was summarized in a note published in the January 1939 issue of *Metal Progress*, p. 68.

inclusions is low in count; the sulphur inclusions are naturally low. As for oxide inclusions, they are almost exclusively found as small isolated grains of alumina to the exclusion of strings or clusters.

The Ugine-Perrin process is, then, a powerful, rapid, automatic method of deoxidation and desulphurization. It allows the production to start with an openhearth furnace and ends with a steel equal from every point of view to those produced by electric furnaces. The most important practical problem is the general condition and the correct temperature of the steel so that the minimum amount of slag will be carried from the furnace with the steel and pass into the special slag, and especially at the beginning of tap. Steelmakers will have to appraise this new process in the light of their own particular problems, taking due account of the types of furnaces they have, the economic conditions at their plant and the customers' requirements for specific steels.

It is important to repeat that the results described above have been confirmed by the production of many hundreds of thousands of tons in several processes and plants.

Table I — Analyses of Steels With Very Low Sulphur

Element						Sulphur Content	
C	Si	Mn	Ni	W	P	Before Perrin Slag	After Perrin Slag
		Steels Made in Electric Furnaces					
0.28	0.27	0.48	4.2	1.36	0.016	0.037	0.005
0.09	0.39	0.53	0.22	0.010	0.014	0.036	0.006
1.00	0.15	0.40		1.55	0.010	0.016	0.005
		Steels Made in Basic Openhearths					
0.62	0.15	0.41			0.025	0.020	0.008
0.38	0.26	0.52			0.029	0.030	0.008
0.125	0.26	0.89			0.044	0.050	0.012
0.83	0.31	0.52	0.46 Mo	2.46	0.017	0.033	0.008

This note is too short to discuss the direct or indirect effect of oxygen or sulphur on steel. It will suffice to state simply the facts acquired by experience: Such steels of very low oxygen and sulphur content and very good cleanliness have excellent impact properties, especially in the transverse direction (see Tables II-a and II-b). The same is true for elongation and contraction of area in the tensile test. The general trend of transverse properties approaches the longitudinal properties of openhearth steels containing the usual amounts of oxygen and sulphur.

On the average the transverse impact properties are twice that required in the corresponding specification, and the hardness is much higher.

Low-Carbon Steels

As far as extra mild steels are concerned (sheet steel in particular) one can say that transverse tensile tests give results almost as good as longitudinal, which is of particular interest for the stamping industry, and appears to justify the excellent results obtained in this field. By way of example, 20-gage sheets (0.039 in.) box annealed at 1250° F. and slowly cooled, produced at Northeast (Valenciennes) from basic bessemer steel poured into slag gave the following transverse results (test pieces are 30 mm. wide with 42-mm. gage length):

Heat No.	Ultimate	Yield	Elongation
5853	46,600 psi.	31,400 psi.	50.0%
5856	45,600	30,400	46.6
5875	52,200	37,200	44.4

The average Mesnager impact of 10 different heats of such steel, taken in the transverse direction of ½-in. plate, annealed in a continuous furnace was 21.8 kg-m. per sq.cm. whereas the average in the longitudinal direction is 21.9.

These results show how well the Perrin process may be adapted to the effective desulphurization of extra-mild steels, even with carbon contents of 0.03 to 0.05%.

Along these lines, Perrin and Jolivet, starting with the idea that pure iron of the Armco type can be rolled without special precaution if the sulphur content is low enough, produced heats of steel with 0.03% carbon and 0.008% sulphur which showed no brittle range whatsoever. The ingots were rolled to blooms, flat bars and sheets under the same conditions as ordinary steels.

This new development in mild steels has been given special attention at the Forges et Aciéries du Nord et l'Est at Valenciennes (Northeast). This steel, produced from a basic bessemer converter, has been given the name "Ugiperval" (an abbreviation for Ugine-Perrin-Valenciennes), and has the following nominal composition: 0.03/0.05% C, 0.15/0.25% Mn, 0.015/0.025% P, 0.008/0.017% S. These steels are sold for the same purposes as Swedish iron, and for the many other uses known to the American trade in ultra-soft steels.

Since Northeast, in cooperation with plants in Denain and Anzin under a new company name "Usinor", is building a new continuous strip mill, every effort is being made to develop the production of deep drawing steels and body sheets

starting from the basic bessemer converter — a problem that is significant from the French and European point of view. Important tonnages of 9-ton ingots have been rolled without any trouble on continuous mills in one large European steel works at speeds comparable to those used for openhearth steels. When used for very difficult deep-drawing work, these sheets have given particularly good results. Strain aging is much less noticeable than in openhearth rimming steels;

Table II-a — Analyses of Ugine-Perrin Steels Made to Meet Aviation and Ordnance Specifications

Heat No.	C	Si	Mn	Ni	Cr	Mo	S
Ni-Cr-Mo (Electric) Steels for Aviation Crankshafts							
37,359	0.27	0.18	0.65	3.07	1.21	0.58	0.007
37,371	0.26	0.21	0.56	2.99	1.23	0.56	0.004
37,380	0.27	0.23	0.53	3.07	1.28	0.52	0.004
Ni-Cr (Electric) Steels for Case Hardening							
37,031	0.13	0.23	0.30	2.78	0.72	0	0.009
37,041	0.12	0.35	0.31	2.88	0.72	0	0.009
Cr-Mo (Openhearth) Steel for Ordnance							
22,468	0.33	0.31	0.52	0.017 P	2.46	0.45	0.009

this is measured by the per cent increase in strength after straining 5% and annealing 15 sec. at 660° F. Comparing steels of the same analysis (C, Si, Mn, P and S) the values follow: Perrin process steel sheets 15%; openhearth sheets 20 to 25%; basic bessemer sheets 27%.

This parallel application of the Perrin process in the production of openhearth rimming steels and basic bessemer killed steels is an interesting development. To me, the most significant possibilities seem to lie in *(a)* the production of extra mild steels, with carbon contents of the order of 0.03 to 0.05% and negligible strain aging; *(b)* obtaining ingots of good homogeneity wherein variation in carbon and sulphur, top to bottom of a 9-ton ingot, is about the same as the error of the analytical methods; and *(c)* good deep drawing properties, leading, in specific instances, to the use of one draw where two had been required previously. Likewise, complaints previously made about aluminum-killed steels (for example, poorer surface or lower weldability) are being overcome because the process controls the residual aluminum content.

It seems a fair statement to say that effective research and scientific development have solved a problem heretofore unsolved in our country — the production and fabrication of high quality sheet steel, rolled from basic bessemer ingots on continuous hot and cold mills. Naturally I can describe only European developments and these may not correspond to American conditions. I can only describe by way of example particular applications of the general method of deoxidation and desulphurization. I feel, however, that production of low-carbon steels low in oxygen and sulphur (approaching pure iron) by a process adaptable to any steel refining furnace, whether converter, openhearth or electric, cannot fail but be of general interest.

It is noteworthy that the Ugine-Perrin process has invaded the field of plain carbon steels when it had been developed originally for high quality alloy steels. As to the latter, it is advantageously applied as a supplement to the electric furnace in the production of nearly all compositions of special steels, except stainless steels for which the alumina slags are not well suited.

Furnace Logs

To give an idea of the rapidity with which the new process works, I can cite three examples of Ugine's methods where a small 500-kw. slag furnace supplies a modern three-phase electric furnace of 25-ton capacity, fed by a 10,000-kw. transformer. The logs of the heats show the total elapsed time is about 3 hr. The accompanying

Table II-b — Tensile and Impact Values

Heat No.	Quench*	Temper	Tensile Properties†		Mesnager Impact Values†	
			Ultimate	Elongation	Longitudinal	Transverse
37,359	1600° F.	1110° F.	165,000 psi.	11.5%	16.1‡	9.3‡
37,371	1600	1110	162,000	11.5	17.4	9.9
37,380	1600	1110	160,000	12.0	17.0	10.2
37,031	1600	480	182,000	8.0	11.8	8.1
	1600	1110	140,000	12.0	22.8	15.1
37,041	1560	480	160,000	9.0	16.4	10.5
	1560	1110	136,000	13.0	22.5	17.0
22,468	1700	1200	125,000 to 136,000	12.0 to 15.7		10.0 to 13.1
Specification Requirement:			>102,000	>12.0		>6.0

*All steels oil quenched.

†Tensile test piece 13.8-mm. dia., 100-mm. gage length. Impact test piece (Mesnager type), 10x10 mm., 2-mm. round bottomed notch.

‡Units are kg-m. per sq.cm.

Fig. 1 — View on Charging Platform of Open-Top, Single-Phase Furnace for Melting Slag

views, from photographs taken by René Castro, chief engineer, Aciéries d'Ugine, show the operations in progress. It may be mentioned that the actual temperature of the steel bath at time of tapping is carefully controlled.

1. A heat of nickel-chromium-molybdenum steel for aircraft. Composition aimed at: 0.20% C, 0.50% Mn, 0.65% Ni, 0.80% Cr, 0.25% Mo.

22:35 End of the preceding heat, repairing hearth, adjustment of the electrodes, charging cold scrap.
22:55 Current on.
0:31 Samples taken to laboratory for nickel and chromium analysis.
0:45 Slagging off, addition of manganese, nickel, chromium and molybdenum.
1:15 Tapping by pouring into slag.
Total elapsed time: 2 hr. 40 min.

2. A heat of ball-bearing steel starting with cold carbon steel scrap and ferro-alloy:

4:50 Current on.
6:35 Samples to laboratory for nickel and chromium analyses.
6:50 Slagging off on extra mild steel.
7:00 Recarburization with anthracite.
7:15 Samples to laboratory for analysis of carbon and manganese.
7:35 Final addition of ferrochromium and ferrosilicon.
7:50 Poured into slag.
Total elapsed time: 3 hr.

3. A heat of bearing steel (remelting bearing steel scrap):

0:30 End of preceding heat, repairing hearth, adjusting electrodes, charging.
0:50 Current on.
2:35 Samples to laboratory for analyses of carbon and nickel.
2:55 Slagging off.
3:05 New samples to laboratory for analysis of carbon, nickel and manganese.
3:25 Addition of ferrochromium and ferrosilicon.
3:45 Poured into slag.
Total elapsed time: 3 hr. 15 min.

These logs, which give a faithful record of the progress of an electric furnace as practiced at Ugine with the Perrin process, show how rapidly this operation can be carried out with a 25-ton furnace, even when making special steels which must satisfy the strictest specifications.

As far as its application to an openhearth furnace is concerned, the advantage is not to cut production time but to obtain improved quality — that is, to produce steels with low sulphur and oxygen contents comparable on every score of cleanliness and mechanical properties with steels processed from the electric furnace. The only

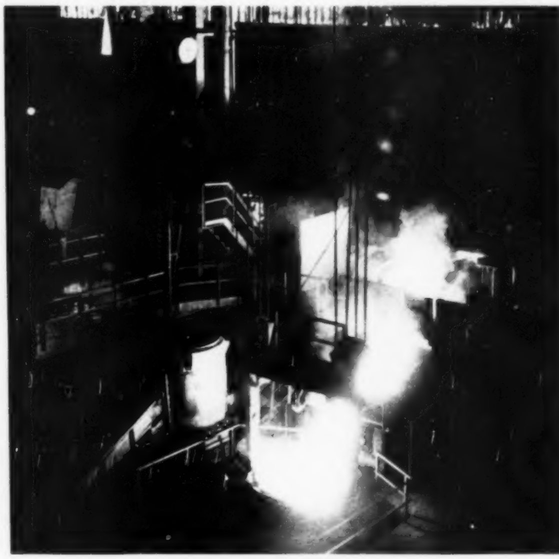


Fig. 2 — Slag Furnace Discharging a Melt Into the Mixing Ladle. At right foreground is a spare furnace shell with slag runner

problem in the openhearth plant is to keep the slag from running out of the furnace with the metal and mixing with the Perrin slag. This has been solved, thanks to various precautions such as rabbling clean, using a properly shaped tap hole and a skimmer on the runner.

Use for Ferro-Alloys and High-Alloy Steels

Perrin has applied his principles to the production of certain ferro-alloys, not only for obtaining high yields from raw materials but at the same time for making alloys with a low carbon content by a fast reaction. An example of this application is the production of ferrochromium from chrome-silicide without ever having the metal in contact with carbon. Thus, the Ugine Works regularly produces ferrochromium with 0.03% carbon by this method. At the Moutiers plant a ferrochromium furnace and an electric steel furnace are synchronized (as has already been described by R. Perrin in *Revue de Metallurgie* for July 1946, p. 185) and regularly produces 18-8 stainless steel with carbon in the neighborhood of 0.03%. Steel of this analysis requires neither titanium nor columbium for "stabilization" — that is, its corrosion resistance is unharmed by shorter or longer heatings within the 750 to 1200° F. temperature range. In addition to this economy in alloying elements, a better ingot surface is obtained.

This method of producing high grade stainless steel has proven so successful over a number of years that it has become current practice with Ugine. Greatly increased capacity is now being installed.

In summary, it may be said that Perrin's process, as exploited primarily at Aciéries Electriques d'Ugine, and now in operation at other notable French works, is able to produce alloy steels from openhearth metal which are equal in quality to the best electric furnace practice — even superior in cleanliness and lower in sulphur, oxygen and hydrogen. Likewise, when starting with basic bessemer steel, low-carbon steel for deep-drawing sheet can be produced, almost void of directional properties, and equal in drawability to rimming openhearth steel. These results are had by merely pouring or teeming the molten steel at the correct temperature (from which previous slag is carefully separated) into a ladle containing about one tenth the weight of a special slag, compounded and melted in a separate small electric shaft furnace.

Fig. 3 — Finish of Pour, Steel From Electric Furnace Into Ladle of Prepared Slag. Photos by René Castro, chief engineer, Aciéries d'Ugine

CRITICAL POINTS

By the Editor

The Navy's Researches in Metallurgy

HOW times have changed! When the Editor made his first trips to Washington, late in World War I, the research work done by the U. S. Navy was sketchy in the extreme. Of course full-size testing of heavy ordnance and armor had been going on at Sandy Hook proving ground for several decades, but any laboratory work at the yards and factories was of the plant-control and trouble-shooting type. Congress had not yet appropriated money to build the "laboratory, complete with shops and engineering facilities" recommended by Thomas Alva Edison and the Naval Consulting Board. The Naval Research Laboratory at Anacostia, down the Potomac from Washington, was not built until 1923, and it was there that A. Hoyt Taylor and Leo C. Young, experimenting with high-frequency radio, observed echoes from a ship peacefully moving down the Potomac. It required a decade of development work by the small staff to produce the first practical radar.

Contrast this with the situation after World War II: Naval Research Laboratory has grown to a group of buildings as large as a state university. Its job is still to study the applications of basic science to the specialized needs of the fleet. Thus its functions are much broader than those of five other equally important institutions maintained by the Navy's Bureaus for perfecting the actual equipment — such as the Naval Ordnance Laboratory at While Oak, Md., the Bureau of Ship's David Taylor Model Basin for studying hull shapes and designs at Carderock, Md., and the Engineering Experiment Station at Annapolis.

But an even more fundamental change has come over the Navy's attitude than the mere expansion of its own facilities, enormous though that may be. It has recognized that Americans are without equals in the application of scientific principles — once they are discovered — but have discovered very few of these fundamentals. So the Office of Naval Research has for three years been sponsoring a long-range program of fundamental researches in all branches of science, from mathematics to psychology, including metallurgy. This work is being done in universities, private research institutions, hospitals and industrial laboratories, literally from one end of the country to another. Contracts are written wherein the Navy recognizes that scientific discoveries by both scientists and graduate students require considerable time in adequate working conditions, unhampered by security restrictions or outside domination; it therefore attempts to create such a favorable atmosphere by furnishing some of the necessary money. The actual subjects for study are usually proposed by the investigator, not the Navy. Likewise, the only string the Navy has on this work is the stipulation that the results must be made public. In the last fiscal year 1131 of these sponsored contracts were operating (including 35 in metallurgy) and the Navy's share of the entire cost was about $20,000,000. . . . What does Uncle Sam get out of it? At the very least a reservoir of scientists who have become familiar with the Navy's fundamental problems; if luck is with us, a considerable addition to basic knowledge whose eventual usefulness is certain, even though it cannot be appraised in dollars and cents.

In visiting the Navy's metallurgical laboratories at Anacostia, Washington, and White Oak, the Editor was especially stimulated by talking with energetic young men, section heads, most of them rather recent recruits from universities and industry. As may be surmised from the preceding account, the Naval Ordnance Laboratory is concerned with perfecting guns, missiles, torpedoes, rockets, bombs, mines, fuses, fire control, detection, range finding and guidance devices. The Editor sensed that in most of these there is

a pronounced trend away from rather delicate electron tubes and complicated circuits toward simpler arrangements of rugged magnets. Hence the extraordinary magnetic laboratories at White Oak (briefly described in "Critical Points" for January 1945). A recent development in magnetic materials was also explained: A grain-oriented 50-50 iron-nickel alloy — the German "Permenorm 5000" — has been perfected and renamed "Orthonol". Its improved properties are due to meticulous care in the melting under high vacuum of purest iron and nickel obtainable, further decarburization and deoxidation by annealing in really

pure hydrogen, and alternate rollings and annealings to line up the metallic crystals in one direction. Its advantages were explained to the Editor, but his knowledge of electricity and magnetism is of the most elementary; nevertheless, he gathered that it will vastly improve alternating current rectifiers and most servo-mechanisms. To impress such as he, the boys in the laboratory had fixed up a Rube Goldberg containing a photocell wired to an arrangement of Orthonol coils about as big as an alarm clock, a motor driven blower, an electric sign, and a wall outlet. When a match was lit nearby, the electric sign instantly flashed "No Smoking", and the fan blew out the match! The amplification of current from photocell to electric motor, they said, was about two *billion* times. One might guess that a thing like this would have some use in a homing missile that would guide itself toward a lighted area. . . . Another new idea under development stems from the French discovery that a particle of pure iron of sufficient fineness (say 0.01 micron, on the order of size as the magnetic "domain" of the theorists) is about as good a permanent magnet as Alnico containing 13% cobalt. All that is necessary is to find out, first, how to manufacture uniformly fine powder and keep it pure and unoxidized; second, how to compact this powder (*pure* powders, mineral or metal, do not stick together very well under pressure); and third, how to sinter it into coherence without destroying its fine-grained nature. The advantage of such an innovation in magnet construction is obviously the saving of cobalt, a highly strategic metal.

Returning now to the more general metallurgical researches under way at the Naval Research Laboratory in Anacostia, the visitor gets the impression that they are headed toward extreme conditions, far beyond those met ordinarily in industry and hence not very likely to be studied elsewhere. For example — the depth to which a submarine, bomb or torpedo can operate depends on the yield point of the shell, so the fabrication of alloys of maximum yield point is being looked into. The tensile stresses in a welded joint when hit by a projectile are two-dimensional and of very high velocity — combinations rather rare in peacetime applications; much needs to be known about the initiation and propagation of cracks as affected by steel composition and microstructure and welding techniques. Again, studies on the effect of small amounts of alloys and gases on the brittleness of iron involve the preparation of iron of highest purity and the measurement of properties under extreme variations of temperature and strain rate. Thus, the metallurgy division at Anacostia carries out investigations in all fields of metallurgy of interest to all branches of the Navy, concentrating on problems which will add fundamental information, and so make metallurgy more of a science.

Heat Treater on Parnassus

BLURB received with the new book by old-time heat treater W. R. Bennett, entitled "Common Sense in Steel Treating":

Perhaps some of the things we Steel Treaters need,
Are a few of the hints we do well to heed.
We must know our steel, that's essentially smart,
For minus this asset, we're licked at the start.

There's another prerequisite this subject requires
A possession of knack as to how to run fires.

Scale is another hazard to shun,
If we want a good job when it's finally done.

When quenching the steel, we must bear in mind facts
Withdrawing it cold will bring about cracks.

Just one more suggestion, before it's too late,
If a piece is quenched crooked, it can't come out straight.
All of these kinks one must surely acquire,
If one wishes to do a good job at the fire.

SELECTION AND HEAT TREATMENT OF CUTTING TOOLS

By Norman I. Stotz
President
Braeburn Alloy Steel Corp.
Braeburn, Pa.

THERE ARE so many contributing factors to the ultimate success or failure of a given tool that years of experience lead the successful tool engineer or metallurgist to be somewhat more humble in appraising his accumulated knowledge. Those who, in pride, assume the one-way approach must too often attempt to explain their failures! A few of the many variables that influence the decision are the design of machine tools, their state of repair, rigidity, method of tool holding, requirement of accuracy in finished product, variation in hardness, structure and surface of material being fabricated, allowable variations in tool design and workmanship, heat treatment, surface treatment, skill of the mechanical operator, and even the psychology and prejudices of the tool designer, heat treater or machine operator. All of these and probably many more factors have to be added to the skill of the toolsteel-maker before a successful tool becomes a reality.

The picture in reality is not altogether an unscientific one. There are sensibly broad principles. We can safely say that practically all twist drills used on high productivity drill presses are made of high speed steel. A little more caution is in order before we say just what *kind* of high speed steel, but we have at least narrowed the field to a related family of toolsteels. The same is true of taps, reamers, hobs, milling cutters, and similar tools — as long as the speeds and feeds at which they are used fall into the high productivity class. And yet, if you were to go to a hardware store today to buy a ½-in. twist drill for the hand-fed drill press you have in your home-hobby basement toolroom, the odds are that you would go home with a straight carbon toolsteel drill.

In order to relate this discussion of *tools* to toolsteels, I have arranged a tentative classification of the most widely used steels. It is shown on page 486, and is presented for the purpose of easy reference to the subject matter under discussion in this paper and a subsequent one on tools for hot work. Items which are in parentheses are meant to be approximate or optional. Many other variations or even different compositions exist, but 90 to 95% of the tools made today are made from the types actually shown on this list.

Likewise, it seems sensible to classify cutting tools and to deal with them as broad classes. I will likely omit some odd types of tools, but the general discussion will develop broad principles that can easily be applied to any type. The metal cutting tools are as follows:

1. Taps
2. Threading tools (chasers)
3. Drills
4. Reamers
5. Mills, hobs
6. Form tools
7. Broaches
8. Single-point lathe tools

Hot Hardness

The author is well known to American metallurgists and tool engineers from a lifetime of manufacturing high-grade toolsteels and promoting their use. He originally formulated a widely-used steel for die casting dies, and (with Howard Scott of Westinghouse Electric) the 5-1-1 chromium-molybdenum-carbon hot work steel. He has spoken before many ⊕ chapters; this article summarizes a wealth of experience on how to avoid troubles in cutting tools arising from improper selection of type and careless heat treatment.

No heat treated high speed tool has any great degree of "toughness" at a Rockwell hardness of C-60 or above. By whatever method this elusive quality is evaluated, the actual figures are low. Elongation and reduction of area in a tensile test (the often-used criterion of "ability to absorb energy before rupturing") are nil; while impact, torsion impact and bending tests will develop values, the figures will vary in a low and narrow range. Even so, within this narrow range we may make a tool which is either worthless or valuable, depending on the selection of the steel, the tool design, the heat treating cycles, and the method of setup in the toolholder.

"Hardness" of cutters presents a dual concept. We speak of the "hardness at room temperature" and also of the "hot hardness". Both are extremely important to any one tool, but they are not necessarily related. A high hardness at room temperature does not mean a high "hot hardness" at the working tip, nor does a low "cold hardness" mean a low "hot hardness".

As far as I know, the true meaning of hot hardness has not been clearly defined. An experienced metallurgist will admit some degree of perplexity on this point. Long before metallurgists were able to make accurate static hot hardness tests, we knew in general that this useful property was enhanced by adding cobalt to the toolsteel's analysis. Even greater results could be had with cobalt, plus vanadium, plus carbon. Many variations in the proportions of these three elements exist in both the tungsten and the molybdenum high speed steel families (Classes A and B of the table). Static measurements of hardness of heat treated tools at supposed working temperatures give higher numerical results for these "superalloy" toolsteels over the cobalt-free types, but if they are not called upon to meet extreme conditions of service they rarely do any better work than the less expensive standard types. The measured hot hardness of the molybdenum high speed steels is generally lower than that of the equivalent grades in the tungsten family and yet, during the height of the war production no tools made of the properly selected and properly heat treated molybdenum high speed steel failed to hold their own with their equivalent steels in the tungsten family, and often they did measurably better.

I believe that hot hardness, measured statically, tells an incomplete story. The dynamic conditions of a tool tip at work cannot be reproduced in a stationary test. Unsolved questions are of this nature: Is it possible that some high speed steels have greater resistance against breakdown at lower hot hardness? Is the *time* required to lower the hot hardness of more importance than the actual hardness value itself? Is not chipping at higher hardness often misinterpreted for abrasive wear? Are not irregular surface conditions primarily responsible for failure of tools by "burning"?

The truth is that we have not as yet, in tool and toolsteel practices, devised any safe assurance that one type is superior to another *except* by actual service and production tests. Ingenuity and experience serve us in good stead as a guide, but they are not yet reduced to either laws or formulas.

I wish to re-emphasize that highly alloyed high speed toolsteels are not justified unless the service demands them; furthermore, unless they are carefully heat treated in a narrower temperature range such steels always fail to return full value for their expensive alloy content.

Relation of Structure to Performance

It is the writer's belief that we have much to learn from the cataloging and study of the structures of hardened high speed steel as related to specific tool applications. If successful tools that have earned their way are not studied, we have a very incomplete picture. We look too casually at the structure of the tools that *fail*, and often close the docket if we locate a trace of a condition that tradition says is harmful. How often the same thing can be seen in a tool that has been called eminently successful!

When the steel has proper chemistry, soundness, cleanness and carbide distribution, I believe

there is a proper combination of intercept* grain size and martensitic needle structure to suit each tool and each application. I further feel that there is a proper heat treatment to attain this, although such heat treatment may vary slightly with each melt of toolsteel. We do not know yet the exact end point for which to aim. We therefore have much basic data to collect and study. We *do* know that coarse grain and coarse martensitic needles lend brittleness at high hardnesses, but with proper mechanical tool support such structures at high hardnesses often make outstanding single-point lathe tools. Maintaining coarse grain and refining the martensite, or refining the grain and retaining coarse martensite, represent two means of increasing toughness (when the working stresses demand such increases) without greatly reducing the actual hardness.

Generally speaking, fine grain size and fine martensitic needles give the greatest toughness. Here, again, this condition can be aimed for without necessarily reducing the hardness values, even though a lower hardness is sometimes desirable. Tools such as taps and drills, subject to severe torsion and by their nature relatively slender in design, require these structures to avoid excessive breakage. Between these two extremes are all types of possible structures which can be obtained by careful and thoughtful consideration of the ability of the tool to stand up to the service required of it.

If the metallurgist sacrifices as much toughness in favor of hardness as is practical, he will generally get the best cutting results in the machine shop.

Unfortunately, we have no easy means of evaluating the martensitic structures, but we can indicate the general range of intercept grain size which gives optimum results for various types of cutting tools (other conditions being simultaneously at optimum value):

Tool Types	Intercept Grain Sizes
Taps	16 to 20
Chasers	14 to 18
Drills	14 to 18
Reamers	15 to 20
Mills, hobs	12 to 16
Form tools	10 to 15
Broaches	10 to 13
Lathe tools	8 to 11

Taps represent an unusually interesting type of tool. Despite the fact that their cutting edges seldom, if ever, reach the temperatures that require high speed toolsteels, a large proportion are now made from such steels as Class A-1 and 2, and Class B-1 and 3. Super high speed steels are seldom used. For hand taps (and dies) several low-alloy types are popular, such as Class E-5 or even Class F-5. These steels are hardened in oil, to prevent warpage of the pitch of the threads.

Taps and dies made of molybdenum high speed steels require careful handling in the high heat furnaces to avoid decarburizing the crest of the delicate teeth. This requirement has favored tungsten high speed, although many successful taps are being made from those varieties that are able to meet the hardening requirements.

Taps are manufactured by two distinct proc-

General Classification of Toolsteels by Analysis

Figures in parentheses mean optional elements

Class	C	Mn	Si	W	Mo	Cr	V	Co
A — Tungsten High Speed Steels								
A-1	0.72	—	—	18.00	—	4.00	1.10	—
A-2	0.82	—	—	18.50	(0.75)	4.25	2.10	—
A-3	1.10	—	—	18.50	—	4.25	3.25	—
A-4	0.74	—	—	18.00	(0.75)	4.00	1.10	5.00
A-5	0.76	—	—	18.50	1.00	4.50	1.10	9.00
B — Molybdenum High Speed Steels								
B-1	0.80	—	—	1.50	8.50	3.75	1.10	—
B-2	0.82	—	—	—	8.00	3.75	2.00	—
B-3	0.82	—	—	6.25	5.00	4.15	1.85	—
B-4	0.80	—	—	1.50	8.50	4.00	1.25	5.00
C — Hot Work Steels — High Speed Types								
C-1	0.35	—	—	11.50	(0.25)	3.50	0.35	—
C-2	0.30	—	—	9.00	(0.25)	3.25	0.35	—
C-3	0.30	—	—	10.25	(0.30)	3.00	0.20	1.5 Ni
C-4	0.36	—	—	5.00	(0.25)	5.00	0.20	—
D — High-Alloy Die Steels								
D-1	2.15	—	—	—	—	12.50	0.60	—
D-2	1.50	—	—	—	0.80	12.00	0.80	—
D-3	1.50	—	—	—	0.80	12.00	1.00	3.00
D-4	1.30	—	—	3.50	—	(0.25)	(0.25)	—
E — Intermediate-Alloy Types for Hot or Cold Work								
E-1	0.35	—	1.00	1.25	1.40	5.00	0.35	—
E-2	0.38	—	1.00	—	1.25	5.25	1.00	—
E-3	1.00	—	—	—	1.25	5.25	0.25	—
E-4	0.45	—	—	2.15	0.25	1.40	0.25	—
E-5	1.20	—	—	1.60	—	0.50	0.20	—
F — Low-Alloy Types								
F-1	0.95	1.25	0.40	0.50	—	0.50	0.20	—
F-2	0.95	1.65	0.25	—	(0.25)	—	—	—
F-3	0.52	0.30	1.00	—	0.60	0.20	—	—
F-4	1.10	0.40	0.20	—	(0.40)	1.35	—	—
F-5	1.20	0.85	0.20	—	(0.60)	0.50	—	—
G — Carbon Toolsteels								
G-1	—	0.30	0.30	—	—	—	—	—
G-2	—	0.30	0.30	—	—	—	0.20	—
G-3	—	0.30	0.30	—	—	0.20	(0.20)	—

*See p. 417, "Metals Handbook", 1948 edition.

esses. The first, known as the cut-thread method, machines the thread in the soft blank and allows a slight oversize for subsequent grinding to final size after hardening and tempering. It is this type that requires especially alert heat treating. The second, known as the ground-thread method, starts with a solid blank heat treated and tempered, from which the teeth are ground. This method eases the heat treating problem, but it requires special grinding techniques to prevent softening of the tooth's crest from the heat developed in grinding. It is now well known that a different grinding technique is required for molybdenum high speed steels than for the tungsten types.

Because of the torsional stresses developed in service and the delicate nature of the cutting points, taps are usually hardened to relatively fine grain sizes, and fine to medium-fine martensitic structures. Only under carefully controlled operating conditions can maximum hardnesses be used successfully in production shops.

Chasers — Much the same general comments made about taps apply to chasers for both internal and external threads, except that flat chasers are usually well enough supported to allow somewhat higher hardnesses and slightly coarser grain sizes. (These tools are meeting much competition from a related class of tools known as thread rolling dies which are made in both the flat and cylindrical form and actually produce the thread by squeezing or pushing the metal into the thread form rather than by cutting.) The use of high speed steels, such as Class A-1 and B-1, and the high-alloy type, such as Class D-2, is being largely superseded by intermediate alloy like Class E-3 which air hardens with a minimum loss of pitch and has enough wear resistance and secondary hardness to offer competitive service.

Drills and Reamers

Drills and reamers present somewhat the same problems. Both are relatively slender tools with fine cutting edges and are subject to severe torsional stresses in service. Both are made in a variety of designs, especially in the flutes and the degree of the spiral, depending on the kind of material to be cut. Drills require steels with the best center structures possible, because of the heavy service required of the point in starting the hole.

Chip clearance for drills is important because the metal that has been cut must find its way out along the flutes. Many of the surface treatments have been found useful in this respect because they reduce the friction on surfaces over which the curl or chip must move.

Power driven drills and reamers are made from a wide variety of high speed steels, although the high-alloy types are restricted to special applications. Class A-1 is the most popular of the tungsten high speeds, although Class A-2 has substantial use. Other than hack saws, the first tools made on a production basis from molybdenum high speed steels were twist drills made of Class B-1. This is still the most popular type, although many drills are made from Classes B-2 and B-3.

Milling Cutters

Hobs and milling cutters are made in such a wide variety of shapes and sizes that an entire chapter could be devoted to them. Every one of the steels listed in Class A and B is used in this large family of tools; the factors that lead to the selection of any particular steel are too

Photo courtesy Research Laboratory, U. S. Steel Corp.

varied to be given here in detail. The majority are made from Class A-1 and Class B-3.

There are several interesting points especially pertinent. Except for very small tools, it is best to make hobs and milling cutters from upset forgings, rather than from bar stock. Forging insures better carbide refinement and distribution; in addition, the "grain" of the steel is curved by proper upsetting so the axis of the grain bands is not parallel to the cutting edges. This is helpful in preventing microscopic cleavage at the cutting edges of the tools.

Machining of hobs is important. Reasonably soft anneals are desired for the rough machining, but for the final smooth machining and backing off operation it is necessary to harden the tools partially. This is often done by oil quenching from about 1650° F. and tempering at 1150° F. to produce about Rockwell C-35 hardness. In this condition the partially machined blanks can be backed off and finished with the smooth surface required. Such finishing treatment, as well as the heavy machine work, produces a strained condition at the surface so that stress-relief is highly recommended before proceeding with the regular hardening operations. Stress-relief usually consists of thoroughly heating at 1200° F. and cooling in air.

Tools of this type can often be hardened to maximum Rockwell hardnesses, relatively coarse grains and relatively coarse martensitic needles—*provided* the design does not involve long slender teeth with relatively weak roots. Properly designed fillets at the roots of the teeth add strength for severe service.

Form tools, either flat or circular, also lend themselves to the use of higher alloy types of high speed steels. Classes A-2 and 3 are popular, although Class A-3 is quite difficult to finish-grind in the heat treated state. The use of somewhat more expensive raw material (as the equivalent high-carbon, high-vanadium molybdenum steels) may easily be worth while because of increased tool life. Since cuts made by these tools are usually light and the tools well supported, high hardnesses and coarse grain sizes are feasible. High speed steels with high vanadium tend to resist grain coarsening, so that hardening at the highest possible heats is desirable.

Form tools require careful handling in hardening to minimize decarburization and the subsequent grinding of the intricate shapes on their cutting surface. Large flat form tools usually have dovetail sections for inserting in the toolholder. Unless the base of this shank is smoothly machined with generous fillets, hardening may result in considerable breakage. Where possible it is advisable to drill a small hole through the length of such tools at the geometric center of the section, thus relieving the quenching stresses at the re-entrant angles of the dovetail which concentrate in the weakest structural section of the steel.

Broaches

Broaches are becoming more popular for many finishing operations. As new, larger and more rigid broaching machines become available, tools of this type are bound to increase in number. Broaches can substitute for and combine various other operations and thus gain enough in production time to justify the original high cost of the necessary equipment. Since the depth of cut is usually light and the broaching tools are rigidly supported, these tools can be hardened to the highest values. Coarse grains with coarse martensitic needles give maximum resistance to abrasion.

While high speed steels of Classes A-1 and 2 and Classes B-1 and 3 are used for most broaches, a growing number are being made from Class A-3 and some of the higher vanadium types of molybdenum high speed steels not shown in our table. Outside of the high speed family, many broaches are made from steels noted for their high abrasion resistance, such as Classes D-2 and 4, E-3 (and even F-1 for intermediate activity tools). A few low activity broaches are made from high-carbon types of Classes G-1, 2 and 3.

Because of their long length in proportion to their cross section, nearly all broaches are heated for hardening in vertical furnaces and quenched vertically; large broaches thus require very deep heating furnaces and quenching baths. Most of them are less than 60 in. long, but some are substantially longer. In addition, the cross-sectional dimensions are irregular throughout the length of the tool. Since accurate straightness is necessary it can easily be seen that the utmost skill is required to assure slow, even and regular heating. Preheating must be thorough and uniform. Careful handling from furnace to the quench and uniform agitation of the quenching bath are essential. Even with the best of technique the tool will come out of the bath with a slight bow. Horizontal presses can be used after the broach has cooled to 1100° F. to remove the worst of the curvature, provided heavy pressures are not applied below 550° F. A good broach hardener must become quite skilled in this technique.

Tempering operations must be uniform and deliberate; in fact, double tempering is preferred. Since tempering further relieves stresses, additional straightening may be required before final grinding. Despite its undesirability, torch heating must be applied to those sections requiring further straight-

ening. The death sentence of many a large and expensive broach can be traced to careless handling at this point. Needless to say, a stress-relief treatment after final machining and prior to hardening is essential.

The production of a perfect broach combines the highest art of steelmaking, tool design and heat treating technique.

Lathe Tools

Our final type of cutting tool, the single-point lathe tool, is one where the extremes of good and bad practice can be found without looking very far. The worst condition applies when a bar of high speed steel is heated in a blacksmith forge, shaped on an anvil, reheated in the same forge for hardening without intermediate annealing, quenched in a bucket of fish oil, ground to shape and sent into service without tempering. As opposed to this, we can picture a similar tool machined all over in the annealed state, carefully heat treated and tempered, and finally ground all over, in addition to grinding the shape on the nose of the tool bit. The irony of this comparison is that our worst example seems to give a creditable account of itself in many applications, and often does just as good a job as our perfect example. There are so many factors that can be taken into consideration to explain this that one often argues himself into a blind alley in trying to analyze all of them!

When properly supported in the holder, tools of this type can be in the hardest state; thus the weakest condition of high speed toolsteels will serve quite well. Aside from grinding proper clearances and rakes on the nose of the tool or bit, not much "tool engineering" is required. Well regulated shops prefer to have a grinding fixture or templet for each tool, rather than rely on the machinist's eye for proper grinding.

Conclusion

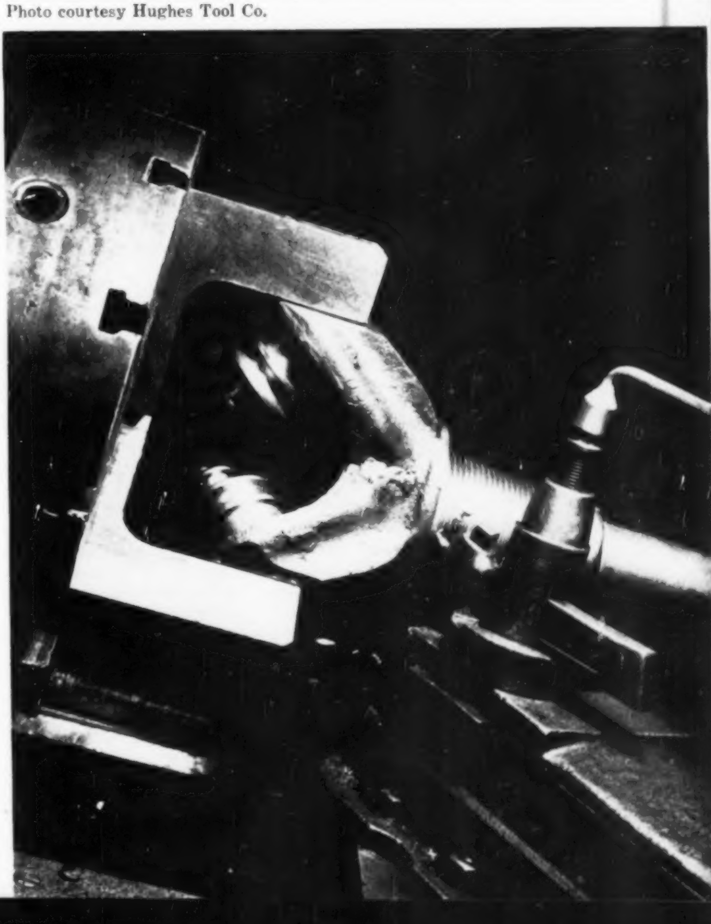
So much for a few remarks on the selection of steels for metal cutting tools, and their proper heat treatment. A subsequent article will attempt a similar discussion of the general subject of "Metal Forming Tools" such as dies, punches and shears.

This first article should not be concluded without some comments on the testing of tools to determine their adaptability to specific applications. Standard physical properties are of use only for general guidance. Cutting tests must be comprehensive to be pertinent. When we have all of these data, we still must test the tools under working conditions.

Cutting tests made on standard logs of constant composition and hardness can be very misleading, unless the conditions are similar to the shop service. This is also true of test blocks for planer tools, drills, taps, and reamers. Under constant conditions of laboratory testing, a given tool can be specially designed or heat treated to perform to best advantage under these closely controlled conditions. Normal variations in service conditions may then cause disappointing results.

For such tests to be truly informative, they should be on a variety of test logs or blocks and with several well selected heat treatments, so that an average over-all performance may be obtained. Even if these tests are run under the strictest control and in minute detail, they serve only as a guide, and do not substitute for the actual service test to determine which is the best tool and the best toolsteel for a given task.

Photo courtesy Hughes Tool Co.



DISTINGUISHED METALLURGISTS

Recipients of the ASM Distinguished Service Award for Meritorious Contributions to Progress in Alloy Steel

Alfred L. Boegehold

Head, Metallurgy Dept.
Research Laboratories Div.
General Motors Corp.

Citation "for his early application of the principles of hardenability to the more intelligent use of alloy steels"

PAST-PRESIDENT BOEGEHOLD'S biography appeared in *Metal Progress* for January 1947, from which it may be found that he, a New Yorker and a graduate mechanical engineer from Cornell, tried a number of jobs before hitting the metallurgical trail at Remington Arms during World War I. There he worked under HARRY WILLIAMS, who in 1920 brought him to Dayton to join General Motors' research laboratory, newly organized by BOSS KETTERING.

In BOEGEHOLD'S metallurgical department many thousands of physical tests were made on steels of all sorts, and the conviction grew that tensile and hardness tests provided no clue to what special advantages (if any) certain alloy steels had over others. He concluded that "tensile strength was always about 500 times Brinell hardness; regardless of composition, a certain hardness seemed to be associated with a corresponding tensile strength.

"Early in the 1930's when nickel-moly 4615 became popular, I shocked FRED GRIFFITHS and BOB ATKINSON by saying that just as good results could be obtained with the older S.A.E. 3115, 5115 (or even 1315, the low-manganese steel) with equivalent hardenability. An opportunity to spread this idea of equivalence occurred when the General Motors Metallurgical Committee revised the physical property charts for alloy steel. In my report the physical properties quoted in various handbooks were replotted as a function of hardness. Charts of this sort, adopted for General Motors Standards at that time, are the ones now in the 'S.A.E. Handbook'.

"This study resulted in a realization by metallurgists generally that the most distinguishing feature of alloy steels was their respective hardenabilities. The logical outgrowth of this idea was today's growing practice of specifying steels principally by hardenability limits and secondarily as to composition."

Martin H. Schmid

Manager of Sales
Alloy Steel Division
Republic Steel Corp.
Massillon, Ohio

Citation "for promoting the intelligent use of alloy steels throughout American industry"

A SMALL AREA in north-central Ohio is the birthplace of the American alloy steel industry — certainly this is true of a commercial and continuing production. Hence it is that so many men, now cited for their influence in the promotion of engineering alloy steels, received their early training in the steel plants of Canton and Massillon.

MARTIN H. SCHMID is no exception. A 1907-graduate in mechanical engineering from Lehigh University, he joined the United Steel Co. at Canton in 1909 as a member of its mechanical department. It was just at that time that United Steel was carrying alloy steels from the laboratory to the production floor. Chrome-vanadium steels had been specified in quantity by Ford Motor Co., and the problems of quantity output had to be solved. Young SCHMID took an important

hand in solving these problems. Successful solution led to the quick adoption of this steel by Dodge, Studebaker, Willys-Overland and other automotive concerns.

In connection with this early work he designed and operated the first heat treating department. His efforts were directed more and more closely into the metallurgical field, and in 1916 he was promoted to metallurgical engineer. Eight years

Martin H. Schmid

later he was transferred to the sales department as assistant sales manager of the company.

So for 40 years his life has been intimately connected with the development and promotion of engineering alloy steels. As United Steel Co. became United Alloy Steel Corp., then Central Alloy Steel Corp., and finally a part of Republic Steel Corp., Martin Schmid continued as one of the nation's authorities on the correct use of alloy steels. While still a metallurgical engineer, much of his work lay in the sales field and his time was spent with engineers, metallurgists and plant superintendents of customers who were fabricating the alloy steels he was making. Men without number throughout America testify to the clear understanding Martin Schmid has of the mutual problems of alloy steel producer and alloy steel consumer, and his constant effort to harmonize their differences to the enduring advantage of both.

Clyde E. Williams

Director
Battelle Memorial Institute for Industrial and Scientific Research
Columbus, Ohio

Citation "for directing the War Metallurgy Committee's researches into alloy steels"

Clyde Williams was born and educated in Utah and, after some 14 years of experience as chemist or metallurgist with mining and smelting concerns in the West, he joined the Battelle staff in 1929, becoming director in 1934. In the estimation of his associates, his outstanding contribution "has been a new method in research — the cooperative method, in contrast to the lone-wolf procedure. In a sense, he is the Henry Ford of high-production, modern, organized research. It is his basic philosophy that research can accomplish better results more quickly if all utilizable talent is brought to bear upon the problem. This is the exact method used by the War Metallurgy Committee for the Government during the war to get research results quickly. With Dr. Williams at the helm of important research operations, there was no lack in skill in their administration, nor drive for their completion."

A summary of this metallurgical work occupies 125 pages in the volume "Applied Physics: Electronics, Optics, Metallurgy" of the series of books "Science in World War II". The rather modest organization of volunteers which comprised the War Metallurgy Committee was expanded to a division (No. 18) of National Defense Research Council. Williams remained in charge and directed a program which included, among other major fields, work on gun steels, projectiles, armor, and metals for high-temperature service. Many American firms and metal specialists cooperated, and important advances were made in all fields.

Frank M. Masters

Owner, Modjeski and Masters
Consulting Bridge Engineers
Harrisburg, Pa.

Citation "for pioneering use of strong structural steels in long-span railroad bridges"

On his 21st birthday, Frank Masters went to work for Ralph Modjeski — a noted bridge engineer, then (1904) at the height of his fame — and found his life work. Masters was an underclassman at Cornell; his job was to inspect steel for the Manhattan and Queensborough bridges, then being built across the East River in New York City. This turned his attention to metallurgy and the night courses in that subject at Carnegie Institute of Technology.

Modjeski was a firm believer in the principles used 30 years before by Captain Eads in his design of the Mississippi bridge at St. Louis (the first engineering use of alloy steel). He early started searching for steels with higher yield strength

than the ordinary carbon steel with its 35,000-psi. yield. The important members of the New York bridges were made of 3½% nickel steel and silicon steel (which was then being used by the Navy). It was MASTERS' duty to inspect and test these special alloy steels, and he quickly found that the mills of that time had great difficulty in rolling large shapes and plates to meet the yield strength specification, yet be ductile enough for the fabrication shops. Nevertheless, these alloy steels were used in the redesigned Quebec cantilever bridge, and in the record-breaking truss span in the Metropolis bridge over the Ohio River.

In their continued search for higher yield strength steels, MODJESKI and MASTERS used Bethlehem Steel Co.'s "Mayari" steel in the cantilever bridge over the Mississippi at Memphis. While certain heats of this chromium-nickel steel, made from a Cuban ore, were excellent, its variability was too pronounced for its logical development until a standardized composition was produced by alloy additions. Such steel, together with 3½% nickel steel, then attracted the attention of bridge engineers for eye-bars used as tension members. To improve the properties and especially the uniformity of these eye-bars, FRANK MASTERS developed the principle of normalizing these large members, often 40 ft. long and weighing a ton — a process adopted by the principal bridge plants.

At the present time practically all of the high-strength steel used in American bridges is the structural silicon steel made to A.S.T.M. specification A94-39. While this steel, with its 0.40% carbon and 0.20% silicon, may not appear to many metallurgists as being an "alloy" steel, its minimum yield of 45,000 psi. with 30% min. reduction of area is much better than the 33,000 yield and 22% elongation specified for structural carbon steel. Nevertheless, the search for better and stronger steels is continuing under FRANK MASTERS' chairmanship by a committee of the American Railway Engineering Assoc. The chairman believes that this extensive program of testing full-size joints in the special steels made by various American mills will result in a specification that can be met by all producers, and a steel that will result in substantial savings in all large structures.

Benjamin Franklin Shepherd

Chief Metallurgist
Ingersoll-Rand Co.
Phillipsburg, N. J.

Citation "for developing the martempering technique"

PHYSICAL and metallurgical testing and control started at Ingersoll-Rand Co. (an international business based primarily on pneumatic rock drills) when BEN SHEPHERD, a high school graduate, was hired for the physical laboratory. The staff consisted of a man and the new boy! Self-educated, he has developed a scientific viewpoint on metal treatment without losing sight of the intensely practical aspects of his work, for no other tools made by man require such a combination of hardness and toughness as a rock drill. To achieve this ultimate, SHEPHERD devoted so much energy and attained so much success that he received the Sauveur Medal for 1942 from the American Society for Metals, and the 1947 "Bradley Stoughton Award for Outstanding Contributions to Metallurgy".

SHEPHERD was early struck by the extraordinary combination of strength and toughness that *should* be obtained in fully quenched and tempered steels — a condition that was seldom achieved in commercial production. It became apparent that much damage resulted from the steep temperature gradient from surface to center of the piece that existed during the quench. To avoid this, he placed an old, occasionally used heat treating process upon a controlled basis. Dubbed "martempering", it consisted of quenching an alloy steel part into molten salt near its M_s point (400 to 500° F.), holding there until temperature equalized, and then air cooling. The reasons and methods used for this process were so lucidly described in his writings that practical utilization mushroomed country-wide. The process was utilized extensively in the war effort on armor-piercing shells, M-4 fuses, and many other vital applications. It is one of the contributions of the last decade that has lifted the quenching operation from its age-old status of an art into that of a controlled metallurgical operation.

Frank P. Gilligan

Secretary-Treasurer
The Henry Souther Engineering Co.
Hartford, Conn.

Citation "for pioneer guidance and 20-year chairmanship of the S.A.E. Committee on Steel Specifications"

AT THE TURN OF THE CENTURY Hartford was the Detroit of the bicycle and sewing machine industries. It was therefore no accident that the budding automotive industry should draw upon it for engineering talent. In this transition from bicycle to automobile the use of alloy steels had been extended from armor plate to mechanical parts. HENRY SOUTHER (a metallurgical consultant in Hartford) and a young man he hired in 1903 for personal secretary and laboratory assistant were in on the ground floor. For this young man, FRANK GILLIGAN, it was a thrilling expe-

rience to accompany his chief to the annual automobile show in old Madison Square Garden in New York, and to record interviews with those responsible for the various cars on exhibition and to seek reasons for the mechanical innovations.

It was therefore at about this time the engineers representing the 28 licensees under the Selden automobile patent (known as the Mechanical Branch of the Association of Licensed Automobile Manufacturers) decided to meet monthly at the Souther Laboratory in Hartford and consider the testing of engines, fuels, lubricants, steels and their heat treatment, and start the standardization of screw threads, rims and tires and similar items that should be interchangeable. Steel company executives, metallurgical engineers, chemists, inventors and pseudo-inventors and entrepreneurs of all types — from many lands — beat a well-worn path to this focal point. During this period HENRY SOUTHER prepared a limited schedule of steel compositions with recommended heat treatments for automobile construction, later to be accepted as the basis for the S.A.E. steels.

This happy combination of circumstances was rudely interrupted when HENRY FORD defeated the Selden patent in 1909. But a small group of keen-witted engineers who congregated socially during "Show Week" as an informal "Society of Automobile Engineers" promptly converted their social group into a technical body, and immediately resumed when the Mechanical Branch of the Association of Licensed Automobile Manufacturers ceased. From that point on, the S.A.E. gained in influence and created engineering and metallurgical progress of which it may justifiably be proud.

No small part of the success was due to the organizing ability of FRANK GILLIGAN, who in 1918 was appointed chairman of the Iron and Steel Division to succeed K. W. ZIMMERSCHIED. This tour of duty extended to 1945, with the exception of a six-year intermission in 1925-1931. As such, his influence on the development of standard alloy steels, accepted by the American steel and mechanical industries, has been indeed outstanding, amply warranting the citation for pioneer guidance of the S.A.E. Committee on Steel Specifications.

Denison Kingsley Bullens

President
New England Auto Products Corp.
Pottstown, Pa.

Citation "for his inspirational work in collecting and publishing American practices in 'Steel and Its Heat Treatment'"

BORN in Newton, Mass., and educated in mining engineering at "Boston Tech", D. K. BULLENS taught nonferrous metallurgy at Pennsylvania State College before deciding he wanted a lot of advanced engineering knowledge in the shortest possible time, "plus a higher degree, if it didn't take too long", as he puts it. Matriculation at Harvard Graduate School of Applied Science gave him neither, but did turn his attention to the microstructure of steel and its relation to heat treatment and engineering properties — subjects that were to underpin his entire future.

In 1911, then, he became metallurgist for Parish Mfg. Co. of Reading, Pa., an early producer of alloy steel auto frames, which currently was having troubles in the forming and heat treating departments — troubles cured by forcing the steelmakers to conform to specifications. Next year BULLENS went with Carbon Steel Co. of Pittsburgh and labored with problems of producing high-grade openhearth steels — especially alloy steel for forgings, battleship deck armor, oil well drills, and safes. Later he became the company's sales representative in Philadelphia.

Here it was that he started a practice as consulting engineer on alloy engineering steels and related problems. "Those were the days when not much was known about the heat treatment of steel and particularly of engineering alloy steel, and much of that information was closely guarded, secret and frequently wrong; when the highest-priced quenching oils were supposed to give the best results; when the canny blacksmith would put on a good show by holding a piece of steel to his nose and tell whether or not it had a high sulphur content!"

In 1915 came the first edition of "Steel and Its Heat Treatment". It contained, for the most part, his personal experience with the heat treatment and use of engineering steels; added to this were ideas gleaned from metallurgical friends, and from wide reading of the existing technical literature in English, German and French. Mr. BULLENS comments thus:

"The preface to this book pointed out that scientific knowledge, engineering applications, and artisan's skill are linked together by the 'human element', and a chapter on this phase of the subject was written. It was a distinct shock to those to whom John Wiley & Sons sent the manuscript for criticism; they demanded the exclusion of the matter on the human element as entirely unorthodox and having no place in a technical book. As Major WILEY humorously put it, 'Take it out, and if the book is a success, *you* become an authority, and *you* then can do as you please.' Actually, the material was split up amongst other chapters, and in the second edition two years later it was put back together again, because by that time the new doctrine of heat application and of 'metallurgical cooks' was well appreciated by the practical man for whom the book was primarily written."

It remains only to say that this book for the "practical man" immediately became indispensable to the technical man and engineer. It has run through five editions, each bigger and better, paralleling closely the growth of the science and art of heat treatment of steel, and in no small measure is responsible for that continuous growth in America.

Physical Research by A.E.C.

THE last report of the United States Atomic Energy Commission to the Congress★ contains a 38-page chapter on research in the physical sciences and 18 pages more on biology and medicine. It notes that large-scale governmental aid is necessary, even in fundamental physical research, because such work "requires the work of men in teams of large size and the use of very expensive instruments". For example, at the Radiation Laboratory of the University of California there are nearly 600 workers in all.

At this research center, "data on the behavior of nuclei under bombardment continued to pile up. There the 184-in. cyclotron, the most powerful in the world, produced important new reactions in which target material bombarded by protons [nuclear particles, positively charged] gave off deuterons [nuclei of H^2]; likewise N^{17} was produced by bombarding heavier elements with deuterons. Here also was the first artificial production of both heavy and light mesons, particles formerly encountered only in cosmic ray processes. Scientists are now on the track of understanding the processes by which mesons are formed and disappear", and their relation to the nuclear binding forces. "To get further into the mysteries of nuclear structure and forces, the A.E.C. is building a proton synchrotron of 110-ft. diameter and 6000-mev. output, by far the most powerful atom smasher ever planned. It will cost some $9,000,000 and be four or five years in the building. It will be something like 18 times as powerful as the 184-in. cyclotron, the present greatest machine.

"The Commission and the Office of Naval Research are supporting jointly a number of other cosmic ray studies. For example, at the University of Minnesota scientists have sent cloud chambers attached to balloons up to altitudes of 100,000 ft. They reveal many types of particles approaching the earth from outer space, including atomic nuclei of middleweight elements such as copper."

The report lists the other important laboratories and gives a general idea of the work progressing in each.† Brookhaven National Laboratory, at Camp Upton, Long Island, is operated by nine eastern universities, and provides a center of atomic research, "which the Commission now plans to keep as free as possible of security restrictions, so that wide academic participation will be possible. The laboratory has departments of physics, chemistry, biology, medicine and engineering. Its regular staff has grown to almost 200, and many other scientists spend part of their time at the laboratory. A program for graduate students will be greatly enlarged in the future.

"In a very complete array of scientific equipment will be a nuclear reactor, now nearing completion, and a proton synchrotron to accelerate nuclear particles to energies about seven times as great as any produced in laboratories today. The reactor will be the first ever built expressly as a tool of research to produce radioactive materials and beams of neutrons for nuclear studies. It will be a graphite-and-uranium pile cooled by air. It will be operating in 1949 . . . .

"The Commission's three national laboratories — Argonne, Brookhaven, and Oak Ridge — with their 58 cooperating universities and research institutions, offer exceptional opportunities for special research and advanced study by university staff members, by post-doctorate students, and by industrial research workers. Training programs at these laboratories, including that of the Oak Ridge Institute of Nuclear Studies, instruct the student in new research techniques, familiarize him with problems of research of interest to the Commission, and provide centers for dissemination of recent findings . . . .

"The scientists of Iowa State College played a leading role in investigating uranium and other little-understood metals and in developing new processes for purifying and working them. The Commission has expanded this work into a major metallurgical laboratory, now being constructed on the campus at Ames, to produce such now-important materials as uranium, thorium, beryllium, and the rare earths, in extremely pure form.

"The rare earths comprise a group of 14 metals ranging from cerium (58) through lutecium (71). [Many of them are produced by the disintegration of fissionable atoms.] These metals have been extremely difficult to separate and very little is known of their properties. They may have a bright commercial future as alloy metals in the manufacture of high-temperature structural materials . . . .

"Metals which might serve as reactor structural materials, moderators, and coolants [in power or plutonium piles] were actively studied during the past year. Zirconium is a possible reactor construction material, but engineers have not considered the metal seriously because of some supposedly fundamental drawbacks. In 1948, new methods of purification and analysis have been developed to determine its true properties . . . .

"In 12 months close to 2000 research reports were produced. Of these, about 1500 are 'classified'; that is, they contain information that the United States must keep from public disclosure for the time being. There are two large obstacles to the nontechnical reporting of research progress in atomic energy — *(a)* the secrecy of the work, and *(b)* the abstruse nature of studies connected with nuclear energy. Nevertheless, the interested layman can get a very good idea of what is happening on the frontiers of atomic energy if he is willing to leave the technical details to the scientist."

★A 200-page book published in January and for sale for 45¢ by Superintendent of Documents, Government Printing Office, Washington 25, D. C.

†Argonne, Brookhaven and Oak Ridge National Laboratories, Los Alamos Scientific Laboratory, the Ames Metallurgical Laboratory, the Radiation Laboratory at Berkeley, and the laboratories connected with the major production plants at Hanford and Oak Ridge.

FACTS AND FANCIES ABOUT AMMONIA CARBURIZING

By Sam Tour
Sam Tour & Co., Inc.
Engineers, Metallurgists, Consultants
New York City

A BRIEF article by the late John A. Dow in 1948 edition, "Metals Handbook" on carbonitriding concludes with this statement:

> "Carbonitriding is still in the experimental stage, although 40 or 50 continuous furnaces, with outputs ranging from 500 to 2000 lb. per hr., are in daily use, and an increasing number of batch furnaces are employed for such processing."

Personally, I prefer the term "ammonia carburizing" to designate the simultaneous nitriding and carburizing of steel in a gaseous atmosphere containing both ammonia vapor and carburizing gases.

The process is quite old. Basically the use of ammonia vapor addition to a carburizing gas is disclosed, described and claimed in U. S. Patent No. 1,152,959 issued to Adolph W. Machlet on September 7, 1915. It would seem that the basic idea has been "rediscovered" a number of times and has been designated by such terms as "nicarbing", "carbonitriding", "nitrocarburizing", "gas cyaniding" and "dry cyaniding".

The situation as described in these paragraphs is by no means unique in metallurgical progress. The number of our operations which were widely used long before they were explained vastly outnumber the ones which were devised after a fundamental principle had been discovered. Nevertheless, it would be well to make a critical summary of the published information in order to locate areas where investigation would likely yield the greatest returns.

The first patent (1,152,959) noted above covers the use of an atmosphere consisting of CO (producer gas), vaporized hydrocarbons, and ammonia, the latter introduced in various ways and in various quantities up to saturation, prior to introduction in the furnace.

Twenty years later the same pioneering investigator and head of American Gas Furnace Co. patented a "process of casing steel articles" (No. 1,995,314; March 26, 1935). He claims that a combination of the ordinary high-temperature gas carburizing and low-temperature nitriding processes can be carried out at intermediate temperatures (3 to 5 min. at 1350 to 1450° F.) in mixtures of 3 to 5 volumes of NH_3 to 1 volume of any common hydrocarbon gas. This gas mixture is said to be neutral to steel up to 900° F.

In treating in this fashion at temperatures below the critical, the objects may be slow cooled and come out file hard. (Slow cooling prevents

distortion.) The case is "malleable" with a gradual softening as the core of the object is approached; cased objects may be bent 45° without surface cracking. It is also claimed that high-carbon steels (up to 0.90% C) may be cased successfully and that the case can be annealed at temperatures of 1500 to 1600° F.

Equal volumes of hydrocarbon gas and ammonia may be used. Under these conditions, the time may have to be increased to 30 min. A distinguishing feature claimed is that the case produced under these conditions is graphitic (at least at and near the surface); it is dark, hard, and self-lubricating.

Machlet's third patent (No. 2,188,226; January 23, 1940) states the inventor's opinion that, at 1600° F., the combination atmosphere does not produce a hard nitride case but rather that the ammonia promotes a deep *carburized* case, essentially free of any surface deposit of carbon. He states that this treatment and temperature result in a relatively soft case when the objects are quenched and tempered. However, by finishing at a final temperature of 1300° F., a much harder case is obtained.

For this reason a furnace construction is recommended so the work enters the hot end (1600° F.) and leaves the cool end (1300° F.). The mixed gas flows in the opposite direction; it is "cracked" immediately and flows to the high-temperature zone where essentially deep carburizing occurs. The work is also skin-nitrided near the exit end — a scheme which is said to avoid a coarse-grained structure.

Descriptive Articles*

The first mention of the process found by the present reviewer in metallurgical literature was by C. R. Austin of Penn State College in *Transactions* ⊕ for 1935 (p. 157). In his experiments on heat treatment in controlled atmospheres, Austin tried mixtures of ammonia and 2 to 12% butane. Carburizing at 1750° F. was very rapid; for example, 0.008-in. case in 15 min. with 8% butane; 0.020-in. case in 30 min. with 10% butane. He believed that small amounts of water vapor increased the rate of carburization. All estimates were made from etched cross sections of heat treated parts.

*Brief mentions, other than those abstracted herein, are "Controlled Atmosphere Generators, Recent Advances in Equipment", by E. E. Slowter and B. W. Gonser, *Metal Progress*, May 1941, p. 563; "Trends in Furnace Design", by J. A. Dow, *The Iron Age*, June 29, 1944; and "Gas Cyaniding Small Parts", by H. N. Ipsen, *The Iron Age*, May 27, 1948.

R. T. Cowan and J. T. Bryce of Surface Combustion Corp. gave a much more complete description of "The Process of Dry Cyaniding" in *Transactions* ⊕ for 1938 (p. 766). In their trials they compared results at 1450° F. in two atmospheres, one made up of 40% natural gas (methane) and 60% "DX" gas,† and the other 50% natural gas and 50% ammonia.

Cowan and Bryce say that ammonia can be used with any usual carburizing gas mixture and that the case composition and depth can be controlled by adjusting the percentage of ammonia. When the *mixture* was introduced in the charging end of the furnace, the results were unsatisfactory, because "interfering reactions" occur, with the formation of water vapor, especially if the carburizing gas contains oxygen. This is also true if the ammonia-carburizing gas is introduced through outlets distributed along the length of the muffle.

Satisfactory carburizing occurred if the *carburizing* gas alone were introduced at the charging end of the furnace and the ammonia entered where the work was up to full temperature. In these circumstances amorphous carbon deposited on the work, and the ammonia later reacted with it to form HCN at the work surface and case hardening began.

The article in *Transactions* contains many photomicrographs, and from them the authors deduce that the amount of NH_3 in the atmosphere does not directly influence the case depth as much as does the character of the case — high ammonia (50%) tends to produce a "white layer". They were able to carburize successfully at 1350° F.

"Carbo-Nitriding of S.A.E. Steel Parts" by Walter H. Holcroft (*Metal Progress*, September 1947, p. 380) describes a continuous pusher-type furnace so arranged that the work can be liquid quenched, cooled in gas blast, or cooled slowly at controlled rate in prepared atmosphere. The atmosphere in the heating muffle is a non-decarburizing carrier gas of 20% CO, 40% H_2, 40% N_2 with small amounts of methane to which the ammonia is added; as the operating temperature increases, the hydrocarbon gas is increased and the ammonia is decreased.

The furnace operates at about 1600° F., somewhat below ordinary gas carburizing furnaces, and produces a case with a thin, tenacious (non-spalling) "white layer" at the surface. This layer is thick and spalls badly if the work is done below 1400° F. Several curves showing carbon-penetration versus depth are printed in this article. One

†American Gas Assoc. Class 102: 71.5% N_2, 10.5% CO, 5.0% CO_2, 12.5% H_2, 0.5% CH_4, dew point 40° F. (See *Metal Progress* Data Sheet, August 1947, p. 256-B.)

example is S.A.E. 1020 after 3.6 hr. at 1640° F. in this gas: 750 cu.ft. per hr. generator gas, 50 cu.ft. per hr. NH_3, 30 cu.ft. per hr. CH_4 (Detroit city gas). The case analyzed 0.54% N_2 and 1.08% C at the surface; 0.70% C 0.010 in. below surface; 0.35% C 0.020 in. below surface. In contradiction to Machlet, Holcroft states that the rate of carbon penetration is the same as in straight gas carburizing.

The scheme of adding some ammonia to a prepared gas carburizing atmosphere has been promoted by furnace builders and ammonia manufacturers, and has been applied by industry for parts which can tolerate no warpage during heat treatment yet need a hard surface with excellent wear resistance. Rather wide differences exist in the published recommendations as well as in the details of the installations. It is another instance of a technical process which has arrived prior to any scientific explanation for its operation. The present article attempts to map those areas where accurate studies must supplant unsupported statements if the metallurgical engineer is to plan this operation with much precision.

Commercial Publication

Armour Ammonia Works of Chicago issued in 1948 a report on "Dry Cyaniding" by its Technical Service Dept., which recommends a mixture of ammonia, carburizing gas and vaporized liquid hydrocarbons, cracked externally or internally with reference to the furnace. In large installations a neutral carrier gas is used to prevent sooting — that is, 30 to 40% of ammonia and 10 to 20% of natural gas is added. For small installations where a carrier gas is not used, atmospheres containing 60 to 70% of ammonia are recommended. Ammonia is said to inhibit the effect of CO_2 and of water vapor, a statement conflicting with an earlier one by Austin that CO_2 and water vapor must be excluded from the atmosphere. It is also said that ammonia lowers the carburizing temperature and increases the diffusion rate of carbon in steel. Also that the amount of ammonia controls the character of the case, a "white layer" being produced at low temperatures.

Summary and Discussion

Machlet's patent of 1915 described ammonia carburizing. In 1941, a description of Lindberg's "hydryzing unit" in *Metal Progress* indicates that its operating principle is almost that patented by Machlet. Holcroft's statements in 1947 generally agree with Machlet's 1940 patent except that Holcroft (as well as Dow) says the rate of carbon penetration is the same as in gas carburizing, whereas Machlet says it is much faster.

Austin's remark about a small amount of water vapor increasing rate of carburization contradicts Armour's statement about excluding water from carrier gas. However, in neither publication is the *amount* of water vapor specified.

Cowan and Bryce agree with Armour that case depth increases when ammonia is introduced, and that ammonia lowers the carburizing temperature and character of the case. (This, also, is in general agreement with Machlet's patent disclosures.) Holcroft indicates that the times for carbonitriding and straight carburizing are essentially the same; this is at variance with Machlet's and Austin's statements, but it may be due to Holcroft's use of relatively lean mixtures of ammonia.

Holcroft and Armour agree that carbonitriding at lower temperatures tends to form a white layer. Holcroft states that carbonitriding below 1400° F. tends to give a spalling case; on the other hand Machlet is quite positive that a spalling case is *not* produced, saying that at 1400° F. carbonitriding is excellent. Holcroft and Machlet agree that high temperature (1600° F.) produces a case similar to that obtained in straight carburizing at 1700° F., and that at low temperatures (1350° F.) the case produced is similar to that obtained in nitriding at 975° F. The nature of this "white layer" is unknown, although Dow (in "Metals Handbook") reports studies by D. M. McCutcheon at Ford Motor Co. on spalling cases made in 20% ammonia atmospheres at 1400° F. which appear to be body-centered cubic solid solution of nitrogen in ferrite. Cases that do not spall contain, in addition, a close-packed hexagonal constituent of greater penetration hardness. Dow believes that the formation of this file-hard surface constituent that forms at high temperature depends as much on the carburizing activity of the gas as the ammonia content, and that it is quite different in essential nature from

the "similar-looking layer formed with higher concentrations of ammonia at temperatures below 1450° F."

There is no agreement as to the best location for introducing the gas into the furnace. Except for Cowan and Bryce, all references indicate that the ammonia and carburizing gas may be mixed before entering the furnace.

It is quite apparent that little is known about the reactions which take place between the steel and the atmosphere constituents in carbonitriding. All observations are reported in rather general terms, and adequate data have not been presented to support some of the statements made. Likewise, contradictions exist in the literature; unsubstantiated statements made by some have been accepted as true and repeated by others. The publications reviewed show micros of cases made with gases containing high concentrations of ammonia, while Dow's brief article in "Metals Handbook" says that the atmospheres may have 1% NH_3 or less for the production of quenched work, from 1 to 5% NH_3 for work cooled in air blast, and up to 15% for heat treatment at low temperatures (1300 to 1400° F.) and slow cooling.

Examples of some of the other unresolved problems may be cited: It is reported that if ammonia vapor is added to an atmosphere that is so rich as to throw down carbon and smudge the work, the carbon throw-down is stopped. Is this due to dilution? Is it due to the increased hydrogen content of the atmosphere stabilizing a higher percentage of hydrocarbons at the temperature of operation?

It is reported that the addition of ammonia increases the rate of carburization. Is this due to some inter-gas reaction such as the supposed formation of HCN (ordinarily regarded as unstable at elevated temperatures) or to nitrogen entering the steel first and creating austenitic iron with a lower critical temperature? If this is true it would imply that the rate of carburization of iron is a function, not of absolute temperature, but of the number of degrees above the austenitic transformation point.

It is reported that an atmosphere containing enough water vapor and carbon dioxide to interfere with carburizing becomes an active carburizer after the addition of ammonia vapors. Assuming that this is true, is it due to the hydrogen of the ammonia consuming the carbon dioxide and stabilizing a higher water vapor content? If so, pure hydrogen should work as well as ammonia. Since the ammonia addition has diluted the gas which was already on the lean side for carburizing, why was the result an increase rather than a decrease in carburizing tendency?

It has been stated that no nitriding of steel occurs at 1600° F. in a mixture of ammonia and carburizing gases. It is well known that ammonia alone, cracking on steel at 1600° F., is very active in nitriding. It would be surprising indeed if this reaction were stopped by the presence of a carburizing gas. Unfortunately, both carbon and nitrogen penetration-depth curves have not been reported.

As regards this rather important commercial process, there is obviously a dearth of scientific thinking as well as a dearth of scientific data about which to think.

CLEANING ALUMINUM SHEET PRIOR TO SPOT WELDING—I

By Gerard H. Boss*
Naval Air Material Center
Philadelphia Naval Base

In a series of papers in former issues of *Metal Progress*,† a beginning was made on a general summary of wartime researches on the spot welding of aluminum. In this article and its sequel an effort will be made to gather the available information on the problem of surface preparation. Wendell F. Hess, then head of the welding laboratory at Rensselaer Polytechnic Institute at Troy, N. Y., and his associates intensively investigated the problem of cleaning, and issued 18 reports (all printed in the *Welding Journal* between June 1942 and August 1946) listed on p. 522. A large proportion of this summary is based on this work at Rensselaer.

An elementary study of the spot welding of aluminum makes it quite clear that a prime cause of trouble is the layer of oxide which covers the metal. This can be removed by mechanical abrasion, but re-forms fairly rapidly;‡ however, if two freshly cleaned sheets are welded, satisfactory joints may be expected.

Prior to the war, all preweld cleaning was done mechanically, chiefly by brushing with steel wool or wire wheel. These methods did provide an excellent surface for spot welding, but they were tedious and time consuming. It would have been impossible to make the 50,000 airplanes constructed in one year during the war, if mechanical cleaning were the sole recourse.

Measurement of Contact Resistance — Dr. Hess and his associates soon found that they needed to determine the contact resistance at the faying plane of sheets to be spot welded. For this they developed a Kelvin double bridge circuit, so designed that oscillographic records could also be made of the current and the electrode pressure during the actual welding operation.

Figure 1 shows a diagram of an apparatus for measuring contact resistance in use at the Naval Air Material Center. The system of transformers is arranged so that 100 amp. pass between electrodes E,E, when the ammeter A registers 5 amp. The vacuum tube voltmeter measures to 0.001 volt. Thus, with 100 amp., the usual condition, the lowest resistance measurable is 0.00001 ohms, or 10 microhms. If lower resistances are to be measured, the current must be increased.

The Kelvin double bridge circuit shown in Fig. 2 was developed at Rensselaer Polytechnic Institute. Another circuit used by G. W. Scott and E. B. Charles at Armstrong Cork Co.'s research

*The opinions contained in this article are those of the writer, and not necessarily the official views of the U. S. Navy.

†Page 227, February 1948; p. 522, April 1948; p. 344, September 1948.

‡Rates of formation and nature of oxide layer have been studied by J. D. Edwards and others in Alcoa's research laboratories. See *Metal Progress*, July and August, 1948.

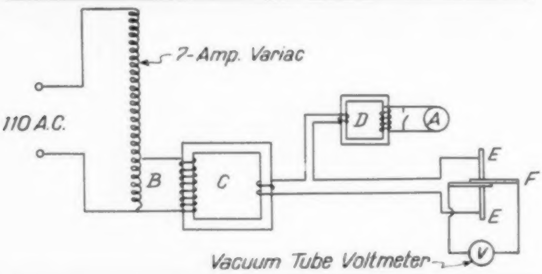


Fig. 1 — Wiring Diagram for Apparatus to Measure Surface Resistance During the Spot Welding of Aluminum Sheets Between the Electrodes E,E

laboratory is described in Reference 7.* The Armstrong Cork apparatus operates on 20 amp., which is considerably less than the others; it is very similar to the circuit in Fig. 1. Messrs. Scott and Charles state that varying the current up to 60 amp. did not change the resistance measured.

In order to use any of these circuits, means must be provided to force the electrodes against the lapped sheets with standard load — usually 500 or 1000 lb. This is readily done with a simple hydraulic jack operating against a fixed yoke. The ram supports one electrode; the other is backed by a platen separated from the fixed yoke by a nest of calibrated springs. Obvious precautions are taken to insulate, electrically, the electrodes from the surrounding mechanism. The jack is pumped up until a gage shows that the springs are compressed a standard amount.

Electrodes are both dome shaped, for easy alignment during seating. The importance of standardized (constant) pressure during the test is illustrated by the results plotted in Fig. 3, from Reference 7, of a series of measurements with varied pressures on two sets of sheets (one much cleaner than the other).

Importance of Surface Resistance — The most bothersome effect of high surface resistance is its effect on tip life, and "pickup". It also causes weld spitting, surface spitting, and irregular shaped welds. The Aircraft Welding Standards Committee of the American Welding Society stated, in *Welding Journal* for August 1942: "It appears that at least 75% of the troubles experienced with surface spitting, weld spitting, irregularity in weld shape, and the extent of electrode pickup can be attributed to improper surface preparation."

The effect of surface resistance on the shear strength of the welds is only slight, if the welding current is set to make satisfactory welds in sheets of low resistance. Figure 4 from Reference 3 shows this, but in this reviewer's mind, graphs such as this are misleading; if the current is adjusted to make a weld of barely satisfactory strength in metal with high surface resistance, the spot welds will be weak in sheets of low surface resistance. This latter point is illustrated in Fig. 5.

Many engineers are aware of the fact that strong welds with adequate fusion can be made in metal of gage heavier than the rated capacity of a machine by "artificially" raising the resistance. It is understood that lacquers for this purpose are on the market. When faced with such a problem on a seam welding job, this reviewer obtained some very highly diluted clear lacquer from the paint shop. The two faying surfaces were lacquered, while the outer surfaces were rubbed with steel wool to prevent electrode roller pickup. While a reasonably good joint was secured, this trick is justified only as a temporary measure, and it should never be permitted on structural parts.

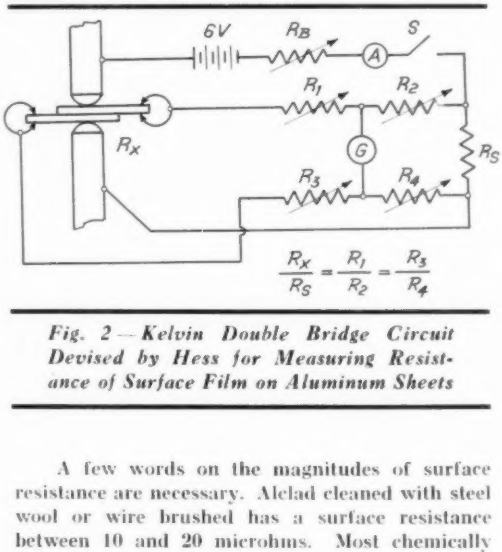


Fig. 2 — Kelvin Double Bridge Circuit Devised by Hess for Measuring Resistance of Surface Film on Aluminum Sheets

A few words on the magnitudes of surface resistance are necessary. Alclad cleaned with steel wool or wire brushed has a surface resistance between 10 and 20 microhms. Most chemically cleaned surfaces have a resistance of 15 to 30 microhms, when cleaned under laboratory methods. Extensive experiments have indicated that production cleaning which resulted in a surface resistance under 50 or 60 microhms is satisfactory. The resistance of uncleaned sheets is around 700 to 1200 microhms.

*For bibliography, see p. 522.

Preweld Cleaning

The need for much cheaper means of preweld cleaning than the early mechanical methods became acute when the aircraft industry began to expand in 1941 and 1942. Also, while alclad 24S-T is satisfactorily cleaned by brushing, bare 24S-T is very difficult to clean because of its content of hard particles of intermetallic compounds. These particles are pulled out of the surface by the abrading medium, and they scratch grooves into the surface as they are dragged along.

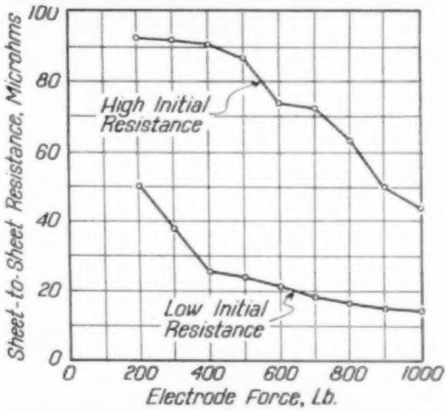


Fig. 3 — Effect of Electrode Force on Contact Resistance of 0.032-In. Sheets of 24S-T

A quicker nonmechanical cleaner is obviously a chemical cleaner in a tank. As a general observation, chemical preweld cleaning is divided essentially into two operations. The first is the removal of all dirt, grease or grit by either an organic solvent or an alkaline degreaser (sometimes both). The second operation is to remove the high-resistance oxide naturally present on the surface, and replace it with another oxide of uniform and low resistance. As will be seen, almost all solutions used for this purpose are acidic.

The first report on cleaning, by the Rensselaer group, was in 1942 (Reference 1). In their investigations of the early deoxidizing solutions, they recognized the need for the prior degreasing, and all specimens tested were degreased with organic solvents as a first step. Possible variables due to these solvents were not investigated. Cold hydrofluoric acid solutions were explored as deoxidizers (oxide solvents) with unsatisfactory results; in all concentrations, these solutions were too critical in the time of immersion for production work. Experiments with cold solutions of sodium hydroxide were also tried without success.

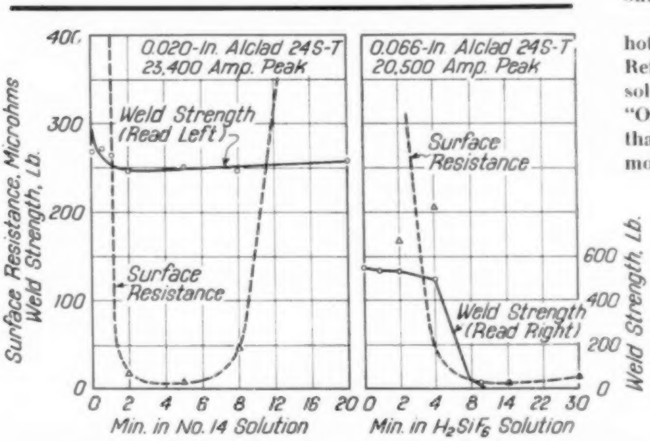


Fig. 4 (Left) — Weld Strength Is Little Affected by Surface Resistance if Welding Conditions Are Correct for Clean Sheets but Fig. 5 (at Right) Shows That This Is not True if Conditions Are Set for Minimum Quality Welds Between Sheets of High Surface Resistance. Alclad, heat treated in nitrate, welded in condenser-discharge welder delivering slowly rising current

Further work on deoxidizers (mainly hot solutions) was reported later, in Reference 2. A very satisfactory hot solution can be made with the proprietary "Oakite 84A". The letter "A" indicates that this is a replacement, with slight modification, of the original "Oakite 84", which contained an unsatisfactory wetting agent. All wetting agents except those based on alkyl-aryl sulphonates tend to decompose in hot acid solutions, forming a frothy scum on the surface. "Nacconal N-R" is a wetting agent of the satisfactory type and whenever a wetting agent is mentioned in this report, "Nacconal N-R", or equivalent, is meant.

"Oakite 84A" is a very satisfactory deoxidizer if used under proper conditions. Under no circumstances should any iron be allowed in the solution, and this excludes steel heating coils. Solutions can be heated with "Karbate" steam heaters or with dried steam.

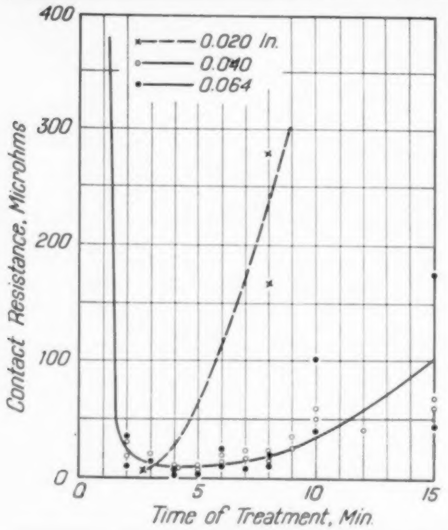


Fig. 6 — Contact Resistance Versus Time in "Oakite 84A" at 180° F. (6 Oz. per Gal.; pH = 1.30) for Alclad 24S-T 0.020, 0.040, and 0.064 In. Thick

Tubing of various corrosion resistant alloys can also be used to carry steam through the tank. Copper alloys, such as brass and bronze, are being used with what their users claim is complete satisfaction. In a conversation with H. Tignor of the Glenn L. Martin Co., the writer was informed that monel metal tubing is satisfactory; however, its service life has been improved considerably by fixing a piece of aluminum on it to provide anodic protection. Aluminum tubing is also satisfactory; alloy 3S would probably be the best. Baskets should be made of aluminum.

Time, temperature, concentration of solution, and (strangely enough) thickness of sheet — at least in thin gages — affect the results. A graph of the contact resistance in microhms plotted against time of treatment in "Oakite 84A" at 180° F. is shown in Fig. 6. The curves shown for the 0.040 and 0.064-in. gages are typical of all satisfactory cleaning curves, subsequently to be described. (In all the following discussions, whenever a solution is described as "satisfactory" it will mean that it has a similar minimum of extended duration.) The curve for the 0.020-in. gage is not satisfactory, for the reason that the minimum time for producing low contact resistance is of too short a duration; no shop can be expected to carry out satisfactorily an operation with such a narrow time limit. Mr. Tignor states that at Glenn L. Martin Co. the temperature is reduced to 160° F. for the thin sheets. The effect of temperature on the contact resistance of 0.040-in. alclad sheet after a 3-min. immersion in a typical solution is shown in Fig. 7.

"Oakite 84A" is supposed to operate at a pH of 1.3; however, experience has shown it performs satisfactorily up to 1.8. Efficient "buffer" compounds are put into this material, so the bath may be too spent to operate and still have the proper pH. It follows that the only way to control the bath is to determine the surface resistance of specimens after immersion in it. This should be done daily, at least. This limitation — as far as pH determination is concerned — is typical of commercial deoxidizers, since most of them are well buffered. "Oakite 84A" is satisfactory for all sheet materials except bare 24S. At Armstrong Cork's plant, the daily tests on the contact resistance of samples were recorded (Fig. 8) for two tanks, one treating alclad 24S-T, the other 61S-W. The former became exhausted in 13 days.

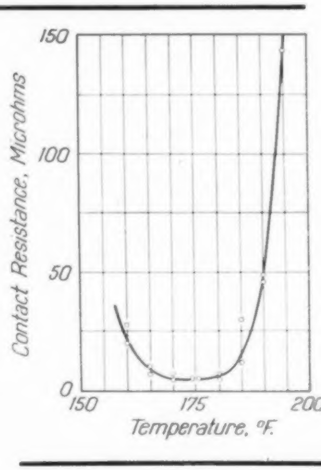


Fig. 7 — Effect of Temperature on Cleaning Solution, 6 oz. Oakite 84A per gal.; pH = 1.30; 0.020-in. alclad 24S-T immersed 3 min.

Nonproprietary Cleaners

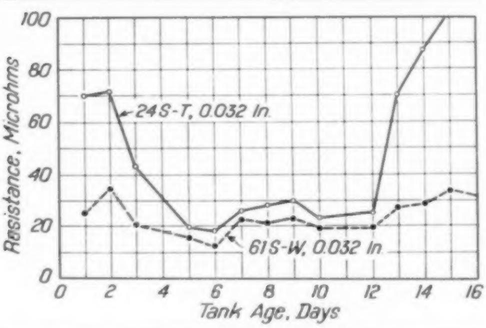
In an effort to find a nonproprietary cleaner, Hess and his associates experimented with a large number of chemical compounds. They found that a simple solution of sodium acid sulphate, $NaHSO_4$, at 180 ±10° F., with 0.2% "Nacconal N-R" as a wetting agent, gave good results. The flat minimum on curves such as Fig. 6 was so very wide that it would seem almost impossible to overtreat aluminum sheet with this solution. Since this is unbuffered, its activity is a function of its pH; however, the range is very narrow, the

solution being satisfactory only between a pH of 1.0 to 1.2. The authors give no data as to the durability of the solution in this range. Other acid sulphates also work well, but $NaHSO_4$ is the cheapest. A 1% solution of sulphuric acid with "Nacconal N-R" is also satisfactory at 180 ±10° F.; the curve of resistance versus time of immersion in this solution was quite similar to that for $NaHSO_4$.

All of the alkaline solutions tested were unsatisfactory.

Bare 24S-T is difficult to clean in many solutions. Hot sulphuric acid and a 1 or 2% nitric acid solution at 180° F. are satisfactory.

Fig. 8 — Life of Commercial Oakite 84A Cleaning Solution, as Shown by Its Ability to Produce Low Contact Resistance on Specimens of Two Aluminum Alloys When Immersed for Optimum Time



The latter is not critical as to composition. It can also be used on alclad, but it is then somewhat better at a concentration of 3%. Tests in the 1% sulphuric acid at 180° F. (pH = 1.05) and in the 1 or 2% nitric acid solutions at 180° F. show that the surface resistance of bare 24S-T has fallen to less than 10 microhms within 2 min. and remains at that figure steadily for immersions up to 30 min. This is true for sheets 0.020 to 0.064 in. thick.

A 10% phosphoric acid solution, used cold, was also satisfactory for bare 24S-T.

It should be emphasized that all these remarks are based on laboratory experiments, which, as is to be shown later, may be quite different from production practice.

(The conclusion of this article, discussing degreasers, room temperature cleaners, and commercial practices, will appear next month.)

CORRESPONDENCE

A Proposal for Research in Metallurgy

PHILADELPHIA, PA.

To the Readers of METAL PROGRESS:

"A Proposal for Research in Metallurgy" by M. G. Corson, published in the January issue, seems to contain an unfortunate, and probably unintended, implication that an embarrassingly large sum of money will be presented to the metallurgical profession, and that really something should be done with it.

Actually, there is a great practical need for fundamental research, and it behooves every scientific worker to help as best he can to obtain financing and adequate direction of an extensive program of such research.

Since the war, fundamental research has been pictured too often as free from all consideration of utility. It is true that it cannot be required to show an immediate and pressing connection with the practical problems of the day. The administrators of fundamental research must take the attitude of Mr. Corson that the research *cannot* be directed so as to show a profit. On the other hand, the need for fundamental research, and its practicality as a national investment, becomes evident immediately any effort is made to tackle any practical research problem except on a wholly empirical basis. The practicality of fundamental research is guaranteed by the research worker himself, who, in all but a few cases, is urgently inspired by the need-to-know, which springs from a need for knowledge. This urgent need-to-know is warrant that the knowledge gained will be useful, without any prior consideration by an administrator of the practical application for the information it is hoped to develop.

Mr. Corson cites the great need for fundamental research in the *theory* of the properties of metals. Research of this kind, free from the prospect of immediate application in industry but promising great application in the future, requires the information on the constants of metals which he wants. The support for it is quite inadequate at present.

The support for fundamental metallurgical research will not be forthcoming if metallurgists assume, as Mr. Corson appears to do, that a benev-

olent Congress, anxious to disperse public money as widely as possible, will hand over to the profession some round sum, like \$20 million a year, arrived at by estimating a "reasonable proportion" of 1% of the national income.

It is apparent from the first that a program should be prepared without too much regard for how much money there may be. It seems to me that the subjects of the program should be listed in decreasing priority according to how much is already being done, with those fields in which nothing at all is being done given the highest priority.

Next, it will be obvious that some categories require minimum expenditures if the work of financing them is to be justified at all, and if the funds available are not to be dissipated by work started but not finished. Third, the amounts of money which can profitably be spent are definitely limited by the availability of qualified personnel. For instance, it will be foolish to try to start programs so lavishly financed that there are no competent teachers left in the schools.

With such a program, pointing to the voids in our knowledge, and with a sensibly prepared budget, the profession should attempt in every way to finance it, from any sources, public or private, devoting the money as received according to the priorities outlined above.

G. M. Foley
Leeds & Northrup Co.

Mr. Corson's Reply

It seems to me that the weakness of Mr. Foley's counterproposal lies in the assumption that private industry can organize fundamental research. This will not happen in the future, any more than it has in the past. I do not know of a single American corporation, with a record of 30 years' profitable production of a metal, that has organized a complete investigation of that metal's characteristics. Even if it had, there is no assurance that all the cards would be put on the table; too often, facts that are unfavorable from a commercial viewpoint are suppressed.

It follows, then, that such work should be done in *national* institutions, properly equipped with facilities and men — full-time, competent workers, not postgraduate students. Likewise, at least three such institutions should tackle every problem, in order that the personal equation should approach zero. I would not expect any legislative congress or parliament to sponsor the fundamental scientific program I envision, but I do expect that some future President of the United States and his cabinet will see the necessity for fundamental work in all sciences, and push a comprehensive program through the likely resistance of Congress.

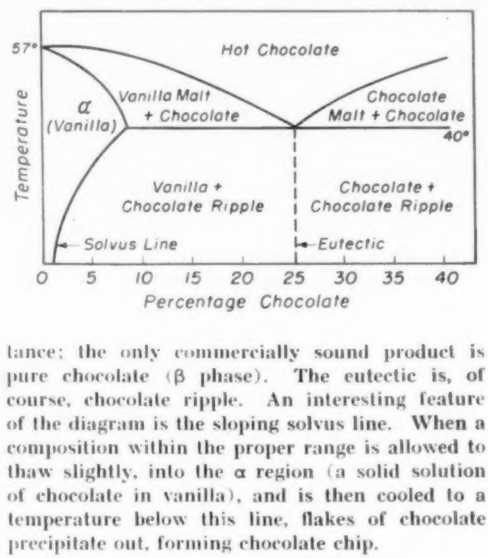
Mr. Foley's company is a leader in its service to industry and practical science. Unfortunately, even his and similar outstanding concerns, in our economy, are not prepared for fundamental work. They cannot do otherwise than switch to things "practical". It is ingrained.

The Chocolate-Vanilla Diagram

Annapolis, Md.

To the Readers of Metal Progress:

The chocolate-vanilla ice cream phase diagram, as shown in the accompanying sketch, was developed at the U. S. Navy's famous Steerage Research Laboratories, located in Annapolis. The men responsible for this development are Dr. Christian of Cornell University and Dr. Thor of the University of Arizona. As can be seen, the most important area lies at the vanilla end of the diagram. The chocolate end is of minor importance; the only commercially sound product is pure chocolate (β phase). The eutectic is, of course, chocolate ripple. An interesting feature of the diagram is the sloping solvus line. When a composition within the proper range is allowed to thaw slightly, into the α region (a solid solution of chocolate in vanilla), and is then cooled to a temperature below this line, flakes of chocolate precipitate out, forming chocolate chip.



D. C. Lind
Midshipman
U. S. Naval Academy

Editor's Note: This interesting phase diagram was printed originally in the *Log*, undergraduate publication of the Brigade of Midshipmen, U. S. Naval Academy. When the Editor first read this report, he was tempted to verify Christian and Thor's results. Perhaps some of the readers of *Metal Progress* will wish to do the same.

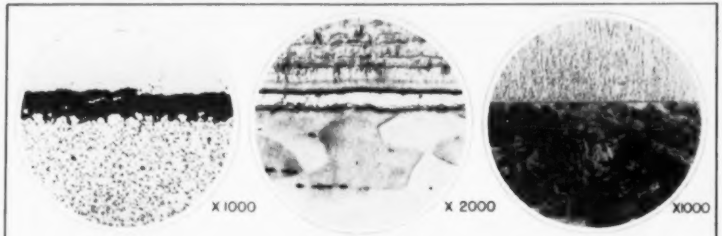
Metallographic Technique for Steel: Polishing (*continued*)

*Sheet 11 of Six Prepared by Research Laboratory, U. S. Steel Corp.**

COMPARATIVE FLATNESS AT EDGE OF SPECIMEN

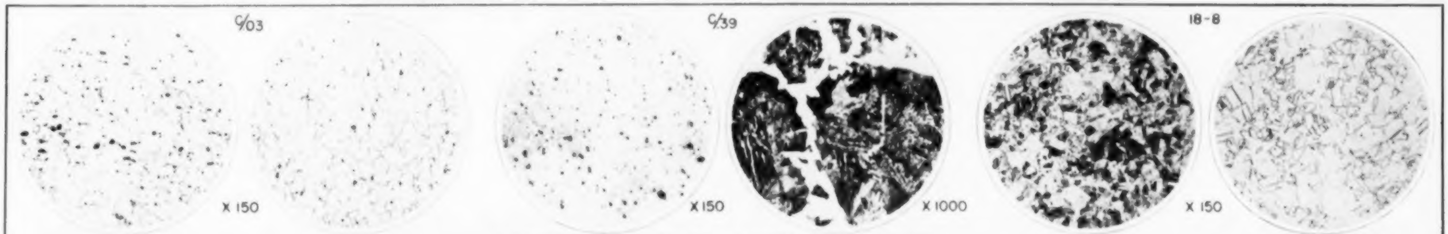
UNMOUNTED X 500 — MOUNTED IN BAKELITE X 500 — MOUNTED IN STEEL CLAMP

PRESERVATION OF EDGES BY IRON PLATING



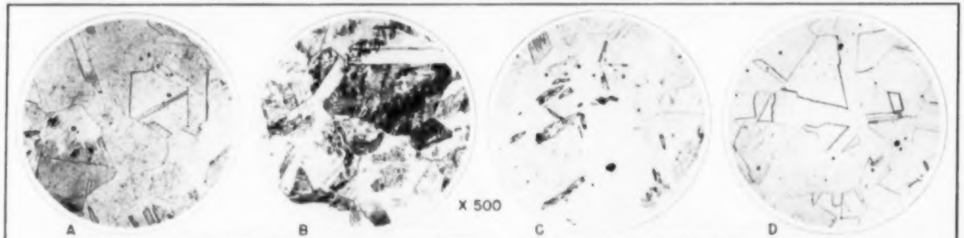
OVER SCALE X 1000 — OVER TIN PLATE X 2000 — OVER STEEL X1000

COMPARISON OF ELECTROLYTIC AND MECHANICAL POLISHING



C/03: ELECTROPOLISHED X 150 — MECHANICAL — C/39: ELECTROPOLISHED, UNETCHED X 150 — ELECTROPOLISHED, ETCHED X 1000 — 18-8: MECHANICAL X 150 — ELECTROPOLISHED

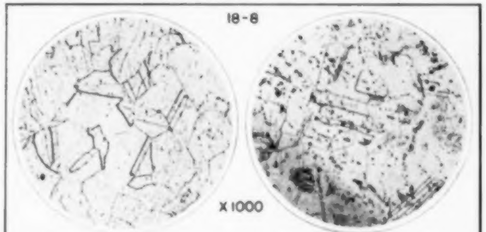
FALSE STRUCTURE RESULTING FROM DISTURBED METAL IN 18-8



A — B — X 500 — C — D

A, B, C-POLISHED MECHANICALLY: FALSE STRUCTURES — D-POLISHED ELECTROLYTICALLY: TRUE STRUCTURE

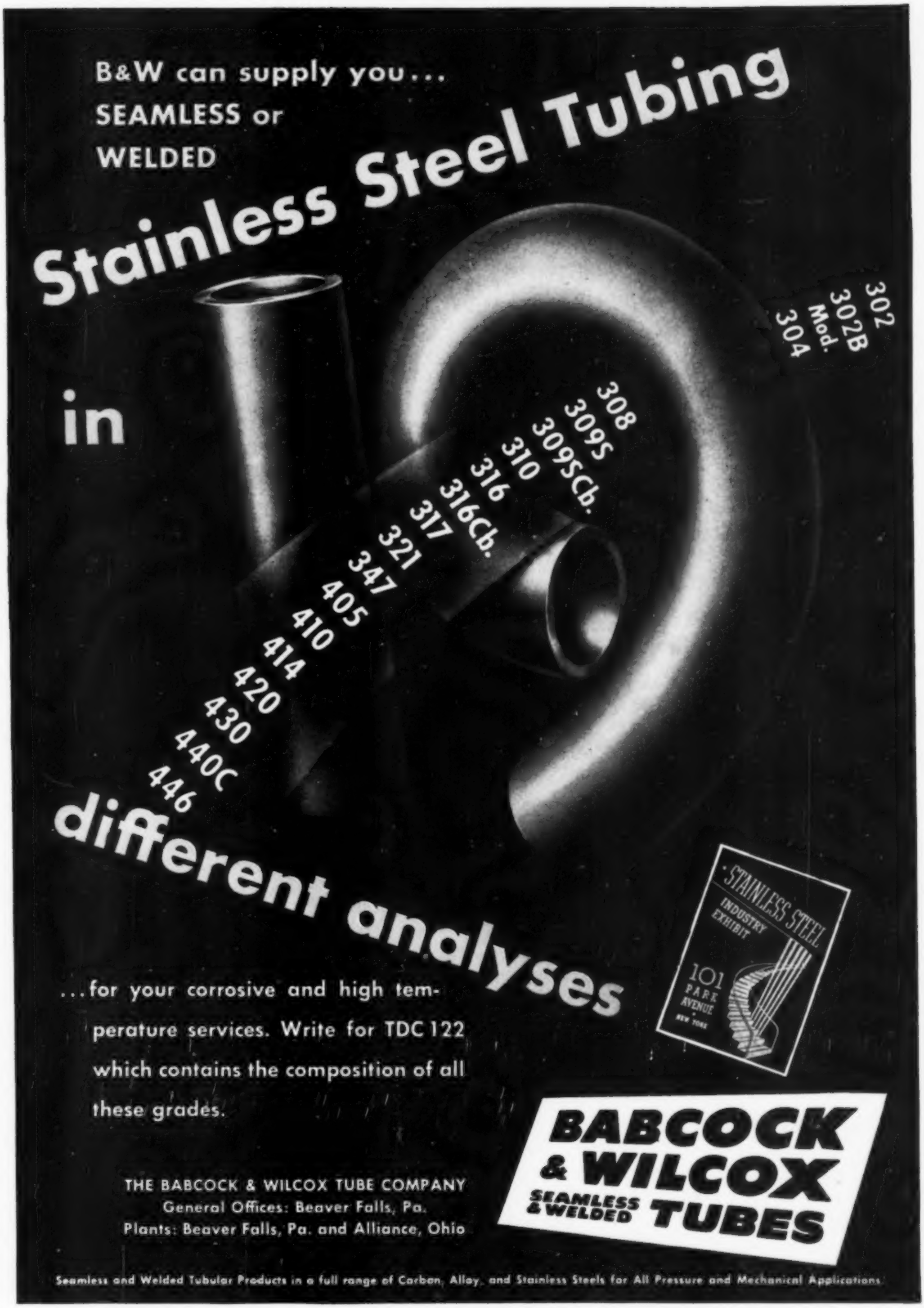
ELECTROPOLISHED



18-8 — TITANIUM TREATED X 1000 — COLUMBIUM TREATED

*Reproductions herein have been reduced to about one third the original magnifications noted

See also "Metallographic Technique for Steel", by J. R. Vilella, published by The American Society for Metals


B&W can supply you...
SEAMLESS or
WELDED
Stainless Steel Tubing
in
302
302B
Mod.
304
308
309S
309SCb.
310
316
316Cb.
317
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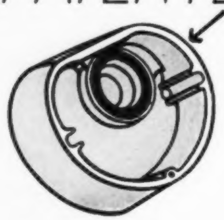

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SOME ASPECTS OF THE HARDENABILITY OF STEELS

By H. J. French
Vice-President
International Nickel Co., Inc.
New York City

I APPRECIATE the honor of being invited to present the sixth Woodside Lecture before the Detroit Chapter of the American Society for Metals. In his earlier days, Mr. Woodside practiced the art of heat treatment and he maintained a keen interest in the subject throughout his professional career. It would, therefore, seem to be appropriate once again to consider that essential component of heat treatment, the hardenability of steels, in the light of present knowledge.

The word **hardenability** may be defined as "the tendency of steel (when heated to temperatures high enough to provide the austenitic condition) to transform, on cooling, to martensite essentially free from lower decomposition products".

In this definition no reference is made to how *hard* the steel may become. The magnitude of the hardness achieved as determined by usual methods of examination will, for present purposes, be designated as "hardening capacity". **Hardenability** is, therefore, concerned with the *rates* or *manner* of transformation of the austenite, while **hardening capacity** represents the *magnitude* of the hardness achieved.

The end point inherent in the concept of hardenability is a martensitic structure which is related to the critical cooling rate. Quenched steels which are characterized as "martensitic" almost invariably have some retained austenite, if cooled at the critical cooling rate or even more rapidly. With so-called "slack quenching" procedures they may contain one or more of the following constituents: ferrite, partially agglomerated carbides, intermediate-temperature transition products such as bainite and, except at greatly retarded cooling, an appreciable amount of austenite.

It would be surprising if these constituents did not exert important influences on the mechanical properties of quenched steels and upon the effects of tempering. In fact, it is well known that they do. However, less attention has been given to the role of austenite retained at cooling rates exceeding the critical than to the study of the structures and properties of slack quenched steels.

Quenching Diagrams — The concept of critical cooling rate goes back more than 30 years to the work of the French metallurgist, Albert Portevin, first published in the *Revue de Metallurgie* in 1917. The idea of a lowering and splitting of the transformations (or "change points") as the rates of cooling were increased has been incorporated in quenching diagrams similar to that reproduced in Fig. 1 for 0.96% carbon steel. The term "troostite" (or "primary troostite") used to designate carbide precipitation and agglomeration directly from austenite would now be replaced by the all-inclusive terminology "intermediate transformation products". Diagrams like the one reproduced were published about 1930, and they showed one interesting feature which since has been largely neglected — namely, that the hardness of the quenched steel reaches a maximum at the critical cooling rate but is not appreciably

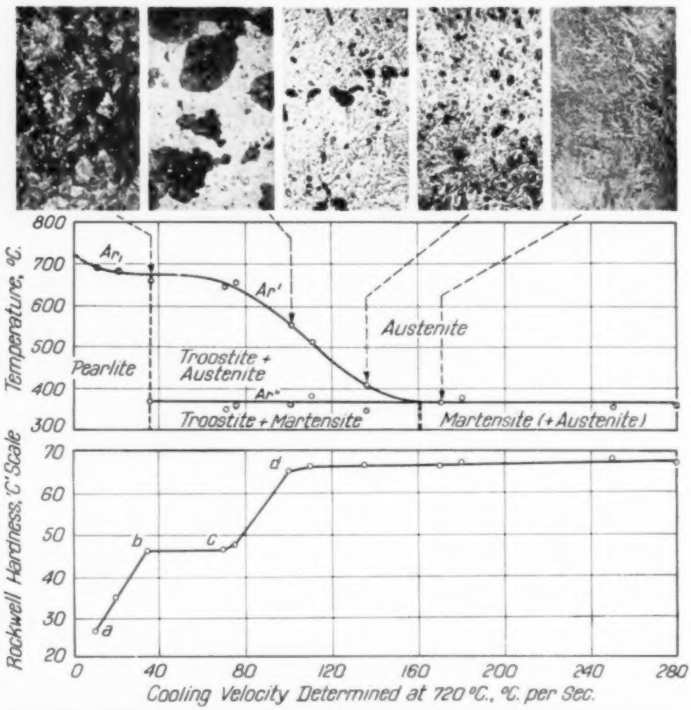


*Fig. 1 — Quenching Diagram for 0.96% Carbon Steel Quenched From 1610° F. Microstructures given at 500 magnification for samples etched with 2% nitric acid in alcohol**

less after cooling at rates somewhat slower. Thus, the procurement of a given high hardness in quenched steels was long ago shown to be not necessarily indicative of freedom from intermediate transformation products in the quenched structures, and hence not a certain criterion of full hardening.

Hardenability Tests — During recent years a comparatively small portion of the effort given to the study of the response of steels to quenching has been allocated to the *direct* determination of critical cooling rates. Instead, short cuts have been employed. While these have nearly all given highly useful information, they have contributed to a widespread and ready acceptance of the philosophy that so long as a given hardness response was achieved when quenching steels (mostly independent of any appraisal based on the amount of martensite present) it made little difference how this response had been achieved. This point of view, while it may have been adequate, is not always metallurgically correct. It may therefore be of interest to examine it in detail, to determine why it has worked and wherein it may not be a tenable philosophy.

Similarity in Mechanical Properties — The usual tensile tests, so widely used in engineering, fail quite generally to differentiate between different steel compositions. It is now many years since Janitzky and Baeyertz† first showed that, for small sections, medium-carbon steels of different compositions were all very much alike with respect to their tensile properties at corresponding levels of hardness between about 200 and 450 Brinell, *provided* the steel and section were such that the critical cooling rates could be exceeded in oil or water quenching, so that through hardening resulted.

A comparable condition is found when considering fatigue on smooth polished specimens. In such tests the fatigue limits are roughly 50% of the tensile strength, and fall within a fairly narrow scatter band at levels of hardness between 200 and 400 Brinell.

Notched-Bar Properties — In the case of notched-bar tests any equivalency of composition is much more restricted. Such tests — whether under impact, as in the Charpy or Izod machines, or whether made under slow bending or in tension — are capable of uncovering differences in fully hardened and slightly tempered steels of various compositions yet of the same hardness, even though these same steels would be indistinguishable by tests on unnotched specimens. Differences found in notched bar tests are considered to be important, because they show the reaction of the

*From early work by the author and associates at the National Bureau of Standards.

†E. J. Janitzky and Mary Baeyertz: "The Marked Similarity in Tensile Properties of Several Heat Treated S.A.E. Steels". Metals Handbook, 1939 edition, p. 515.

Table I — Notch-Bar Properties of Several Steels at Different Hardness Levels

Tensile Strength	Rockwell Hardness	S.A.E. 2340		S.A.E. 5140	S.A.E. T1340
		Heat AA	Heat E-3		
		Concentric Notch Strength			
200,000	C-40	285,000	280,000	265,000	265,000
225,000	C-45	285,000	265,000	200,000	140,000
250,000	C-49	260,000	230,000	180,000	125,000
275,000	C-52	235,000	200,000	175,000	125,000
		Notch Ductility			
200,000	C-40	3.0	2.5	1.7	1.4
225,000	C-45	1.5	1.0	0.5	0.2
250,000	C-49	0.8	0.7	0.3	0.1
275,000	C-52	0.5	0.5	0.2	0.1
		Eccentric Notch Strength			
200,000	C-40	135,000	120,000	90,000	90,000
225,000	C-45	115,000	100,000	60,000	40,000
250,000	C-49	90,000	85,000	55,000	35,000
275,000	C-52	70,000	65,000	55,000	35,000

metal under multi-axial stresses characteristic of many service conditions which may cause ordinarily ductile metals to fail in a brittle manner.

Charpy and Izod tests are sensitive to basic changes in the properties of metals, but customarily they provide only energy values for comparison. Data of a corresponding nature can be obtained from slow bend or static tension tests of notched bars by multiplying the observed strength by values of ductility. However, the latter tests can yield information of even wider practical significance.

Notched tensile tests recently reported by Sachs and his associates* for several ternary alloy steels are reproduced in Fig. 2. All of these steels had similar but not identical Jominy hardenability characteristics.

This work shows large differences in notch strengths between the different alloy steels (and even different heats of the same kind of steel) oil quenched and tempered to the same strength levels within the hardness range C-40 to 50, equivalent to tensile strengths from about 200,000 to 275,000 psi. The two melts of 3½% nickel steel both showed considerably higher notch strengths than the chromium steel, which in turn showed notch strengths markedly above those of the manganese steel. Furthermore, the steels with highest notch strengths showed highest notch ductility. The magnitude of the differences under discussion will, perhaps, be clearer from the tabular summary provided in Table I.

The several steels used in the experiments outlined above were all oil quenched and tempered in a usual manner in sections close to 0.5-in. diameter, but their structures as viewed under the microscope were not the same. The nickel steels with the highest notch strengths were martensitic and free from ferrite and bainite. The chromium steel and the manganese steel had small amounts of high-temperature bainite which, in the absence of contrary information, might be assumed to have caused the

*G. Sachs, L. J. Ebert and W. F. Brown, Jr.: "Comparison of Various Structural Alloy Steels by Means of the Static Notch-Bar Tensile Test", Technical Publication No. 2110, American Institute of Mining and Metallurgical Engineers, 1946.

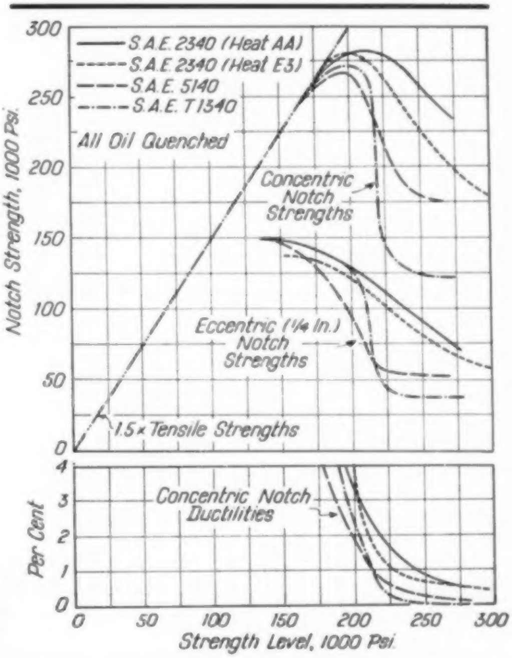


Fig. 2 — Notch-Bar Properties as a Function of Tensile Strength Level for Various Alloy Steels, According to Sachs and Co-Workers. See Table I

lower test values. To check this, one of the nickel steel melts and the manganese steel were hardened in brine and tempered in smaller sections, 0.3-in. diameter, notched 50%, and tested. Both steels now had fully martensitic structures, with some retained austenite. As shown in Fig. 3, the nickel steel, 2340, showed notch strength and notch ductility superior to the manganese steel, T1340, at high hardness levels corresponding to static tensile strengths of about 200,000 to 325,000 psi.

The magnitude of this difference between the

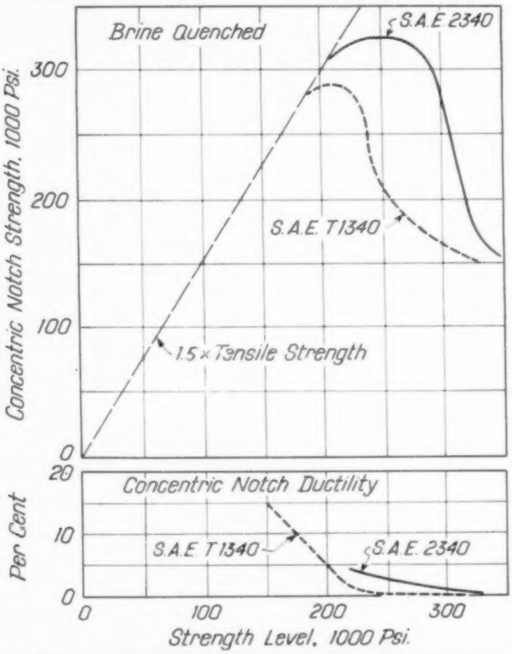


Fig. 3 — Results of Concentric Notch-Bar Tests on Brine Quenched Medium-Carbon Manganese Steel and Medium-Carbon 3½% Nickel Steel Tempered at Different Temperatures (Sachs)

two steels, brine quenched and free from intermediate decomposition products, may be shown by the following comparisons: At a strength level of 300,000 psi. the manganese steel had a notch strength of only 162,000 psi., whereas the nickel steel showed 280,000 psi. — some 70% more. At a somewhat lower strength level of 250,000 psi., the manganese steel had a notch strength of 200,000 psi., and the nickel steel 325,000 psi.

The conclusion may be drawn that the mechanical properties of martensitic structures with retained austenite (such as are encountered in medium carbon steels, when brine quenched) may depend upon the *composition* of the steel. Variations in notch strength have been shown between two alloy steels in Fig. 3, and other results, which are available but which are not recounted here, show that carbon content itself may exert a profound influence; reduction from a level around 0.45% C has a distinctly beneficial influence on the notch strength and notch ductility at high hardness levels in alloy steels.

American Quenching Practice

It might be assumed, from the wide discussions of hardenability and the extensive literature on the subject, that nearly everyone would be able to select steels and treat them so as to provide a structure as-quenched, before tempering, consisting of full martensite and retained austenite, but recent investigations in England and in this country have given some surprising information. Comments here will be restricted to the American experience.

Sixteen alloy steel parts were selected from important products of American industry and representative samples set aside after the quench but before tempering operation. These samples included parts such as automobile drive shafts and transmission gears, oil-well tool joint pins, aircraft landing gear parts, bearing races, automotive ring gears and pinions, aircraft engine connecting rods, die blocks, drill collars, machine tool forgings, springs. The steels from which these parts were made included types commonly known as S.A.E. 4340, 4650, 3140, 4140, 5140, 6150, the 8600 series with carbon between 0.45 and 0.60%, and 1340. Three of the 16 samples were carburizing steels, S.A.E. 4620 and 4320.

The different parts were sectioned and examined under the microscope to determine the quenched structures. (This work was done by G. R. Brophy of the research laboratory, International Nickel Co.) The surprising result of these examinations was the finding that in only three of the 16 manufactured parts did American commercial quenching practice provide martensite free from the lower products of austenite decomposition. In other words, less than 20% of the total of selected parts could be classed as through hardened in their working sections.

If this is an accurate index of all American industry, it becomes important to compare different steels, not only after quenching at rates *above* the critical and tempering, but likewise on the

H. J. French, one of the earliest metallurgists to study the quenching phenomena in a scientific way, and Past-President ⊕, calls attention to the fact that steels with the same end quench hardness curves (that is, the same "hardenability", in present-day parlance) may have much different toughness, as measured by notch-bar tests at equal hardness and strength levels. This is true even though the steels may retain substantially equal amounts of austenite after the quench. Steels of good hardenability but poor toughness act well in service in those parts that are overdesigned, but when optimum properties are required in critical sections of important machines or structures, the above factors must be considered.

basis of the incompletely hardened or "slack quenched" structures. To pursue this thought, the original 16 quenched parts were tempered in the laboratory, using the same tempering temperatures and times for each as they were destined to have in production. After such tempering, Charpy V-notch specimens were machined from the parts and tested to secure an indication of biaxial stress behavior. Results for a few of the tests are included in Table II.

Slack Quenched Steels — With the object of determining what, if any, deterioration in service performance might result from the slack quenching these parts were obviously getting in production, additional Charpy V-notch test specimens were cut from each of the original parts, these small specimens were through hardened in the laboratory from the stated quenching temperatures used by the manufacturers, and then tempered to the same hardness as that achieved after the manufacturers' quench and the later tempering in the laboratory.

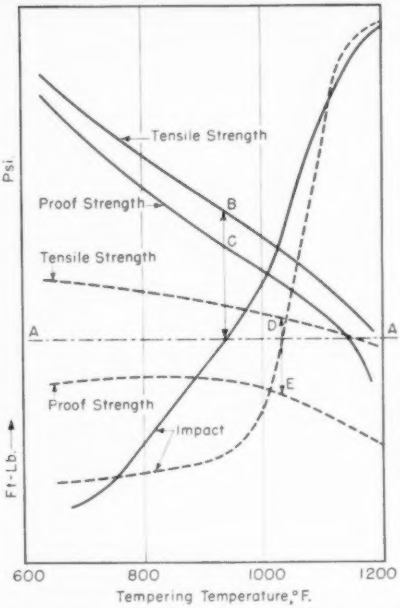
A few of these results have been incorporated in Table II to illustrate the effects of slack quenching the different steels. In most instances the parts which were requenched to provide full martensite and then tempered show a considerable improvement in mechanical properties. In the four examples comprising the Table, notch values obtained were 15 to 36% higher after the laboratory retreatment.

The differences between full martensite with retained austenite and the slack quenched structures, when tempered, have been shown by Griffiths and co-workers* in somewhat different manner. In Fig. 4 the pattern of change on tempering steels which have been transformed in

*W. T. Griffiths, L. B. Pfeil and N. P. Allen: "The Intermediate Transformation in Alloy Steels", Second Report of the Alloy Steels Research Committee of the Iron and Steel Institute, London (1939). Special Report No. 24, Section XII, p. 343.

Table II — Notch-Bar Test Values and Structures of Four Steel Parts Taken From Commercial Production After the Quench

Steel and Part	Size	Quenched Structure	Full Commercial Heat Treatment			Notch-Bar Specimens Retreated for Tempered Martensite			Improvement in Charpy Value
			Quench and Temper	Hardness	Charpy V-Notch	Draw	Hardness	Charpy V-Notch	
1340; Drive shaft	1⅛-in. dia.	Practically all bainite	1675° oil; 1100°	C-28	65 to 70	1100°	C-29	75 to 81	15%
6150; Landing gear	⅝ x 3½ x 10 in.	Martensite with small amounts of bainite	1600° oil; 925°	C-44	10 to 11	925°	C-44	15 to 15	36%
8660; Coil spring	1⅛-in. dia.	Small amount of bainite in martensite	1500° oil; 975°	C-43	20 to 20	975°	C-43	25 to 26	20%
3140; Drill collar	Surface area of 6½-in. dia.	Bainite and martensite	1575° water to 375°; 950°	C-30	20	950°	C-31	25	25%



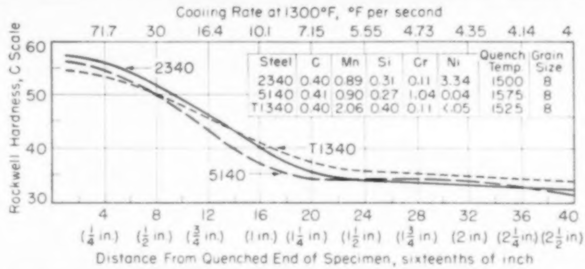


Fig. 5 (Above) — End Quench Hardenability of Three Steels Investigated by Troiano, Whose TTT Diagrams Are Shown on Page 511

Fig. 4 (Left) — Effect of Tempering on Steels Transformed in the Martensitic Range (Full Lines) and in the Intermediate Range (Dotted Lines), After Griffiths, Pfeil and Allen

the martensitic range is shown by the solid lines, and similar data for steels transformed in the intermediate temperature range are plotted in the dotted lines. The significant differences may be illustrated by assuming a desired notch test value represented by the line *A-A*. The martensitized steel would provide a proof stress of *C* at a tensile strength of *B*. The same steel, initially transformed in the intermediate range, would provide a much lower proof stress *E* at the lower tensile strength *D*.

In his 1945 Howe lecture on "Toughness and Fracture of Hardened Steels" before the American Institute of Mining and Metallurgical Engineers, Marcus A. Grossmann pointed out that the intrusion of ferrite at the grain boundaries of the mother austenite in hardened steels caused an appreciable decrease in notch-bar test values. Isothermally transformed samples, first austenitized at high temperatures to coarsen the grain, ruptured in the relatively soft ferrite. He thought that this was due, in all probability, to a low fracture strength of ferrite, and to the fact that its opportunity for plastic flow under stress was sharply restricted when hemmed in by the surrounding hard martensite.

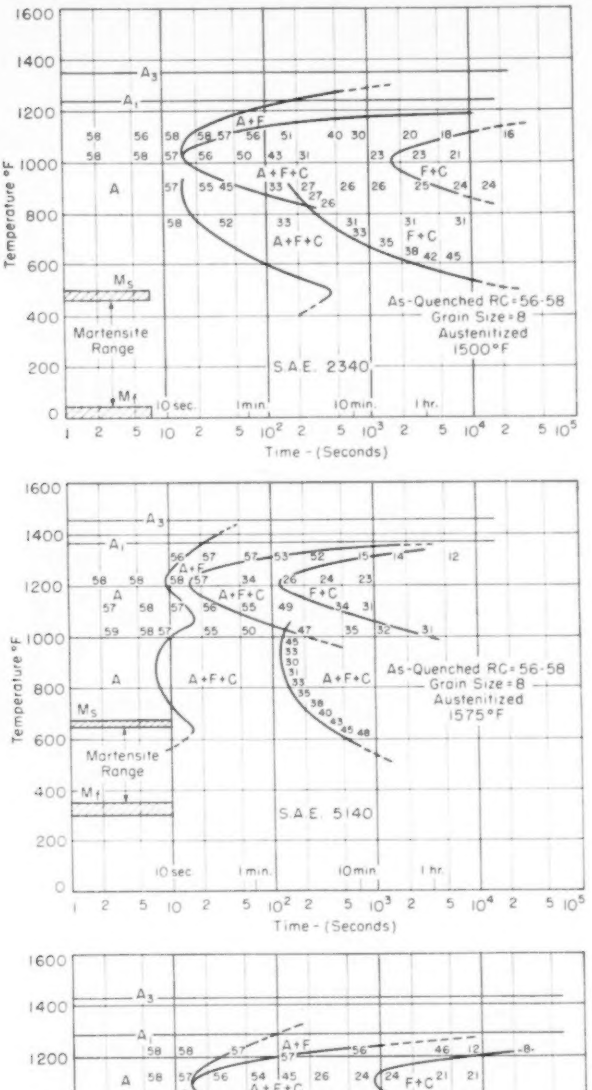
Experiments with S.A.E. 4140 and 3140 steels showed that toughness was not recovered in such mixed structures until the amount of precipitated ferrite reached some 30 to 50% by volume. Steels with such large amounts of ferrite cannot be classed as "hard" or "hardened", but clearly there is a radical reduction of notch-bar test values with the intrusion of the soft ferrite in small quantities into the hard steel structures. This will be evident from the data listed in Table III.

From these and other results available, the conclusion would seem to be justified that slack quenching is to be avoided if the best mechanical properties are to be secured. But a question arises whether the deterioration from ferrite intrusion, or from the mixed structures produced by

Table III — Effect of Proportion of Soft Structural Constituent on Notch-Bar Toughness of Hardened S.A.E. 4140 Steel★

Time at 1300° F.	Rockwell Hardness	Energy, Ft-Lb.	Per Cent of Ferrite (Plus Pearlite)
None (direct quench)	C-51	17, 10	None
0 to 1 min.	51	16, 9	None
5 min.	51	5, 5, 5	1
10 min.	50.5	5, 5, 5	2
20 min.	47	4, 4, 4	5 F + P
40 min.	47	4, 4, 4	
1 hr.	42	4, 4, 4	18 F + P
2 hr.	19	7, 7, 6	>50 F + P
6 hr.	C-7 (B-88)	35, 34, 39	100 F + P

★Austenitized at 2100° F.; after stated time for transformation at 1300° F., quenched in oil and then tempered at 400° F. (W. K. Smith; reported by M. A. Grossmann)



cooling rates slower than the critical, is equally bad in all steels — and especially in those whose end quench hardness patterns are quite similar. This question will now be examined.

Transformation Modes*

The isothermal transformation diagrams of three steels with comparable end quench hardness patterns will serve to illustrate the point that austenite decomposition does not necessarily proceed in like manner in different steels, even though hardness patterns for end quench specimens may be the same. The three steels chosen for discussion had nominal compositions of 0.40% carbon and the usual amounts of incidental elements. One contained 3½% nickel, the second about 1% chromium, and the third 2% manganese (for convenience designated as T1340 steel). End quench hardness patterns are given in Fig. 5 while their isothermal transformations are shown in Fig. 6.

The three diagrams of Fig. 6 may appear to be closely related to each other, although they vary in one major respect from the isothermal transformation diagrams familiar to most metallurgists in showing, separately, the bainite and pearlite transformations (both beginning and ending) at intermediate temperatures. But sharper inspection reveals that the three diagrams differ among themselves. Thus, at temperatures near and above 1000° F. there are two sets of curves in the diagram for chromium steel, 5140, overlapping with respect to temperatures but separated with respect to times.

In the nickel steel (and also in the manganese steel) diagram there is a more complete overlapping of the bainite and pearlite reactions both with respect to temperature and time, but the beginning and ending curves have forms which indi-

*The work discussed in this section was done by A. R. Troiano and is reported in ⊕ *Transactions*, Vol. 41, 1949, p. 1093, in a paper entitled "Transformation and Retention of Austenite in S.A.E. 5140, 2340 and T1340 Steels of Comparable Hardenability".

Fig. 6 — Isothermal Transformation Diagrams of the Three Steels of Fig. 5

cate that austenite transforms completely by one means or another at all intermediate temperatures.

As a specific example, decomposition of austenite in the nickel steel at a constant temperature of 935° F., as shown in Fig. 6, starts in about 10 sec.; the product is bainite and the proportion of bainite grows for about 20 sec. (total time, 30 sec. at temperature). Pearlite then begins to form, along with the bainite, from the remaining austenite. Simultaneous formation of these two products continues until about 2 min. has elapsed since the initial quench; no more bainite forms, but pearlite continues to form from the remaining martensite until all the latter has transformed (about 30 min. total at 935° F.).*

Overlapping of a similar nature (formation of two transformation products simultaneously) is found in the manganese steel T1340 but at slightly higher temperatures. A condition corresponding to that described for the nickel steel at 935° F. is found in the manganese steel at about 1000° F.

There are thus two essential differences in austenite decomposition at constant intermediate temperatures between the nickel and the manganese steels, on the one hand, and the chromium steel on the other. In the nickel and manganese steels, austenite transforms by the production of bainite, and later by the simultaneous formation of pearlite; the pearlite continues to form until the austenite completely disappears from the microstructure. In the chromium steel, on the other hand, the austenite decomposition is incomplete at the time the transformation into bainite stops, for all practical purposes.

These differences are not readily apparent when considering only the TTT curves of Fig. 6, since the line representing the *end* of a reaction does not necessarily indicate that the transformation is *complete*, merely that reaction has stopped. As one illustration of the significance of the two modes of transformation, there is given in Fig. 7 for the 2340 nickel steel and the 5140 chromium steel a summary of total dilation and hardness when each of these two steels is isothermally transformed at different temperatures throughout the range 600 to 1000° F. Total dilation and hardness both decrease in the nickel steel as the austenite is decomposed at progressively higher constant temperatures within the specified range.

In the chromium steel, the total dilation generally decreases with increase in transformation temperature and so does the hardness at transformation temperatures up to about 900° F. At higher temperatures, the hardness again increases, due to the incomplete decomposition of austenite. At temperatures in the neighborhood of 1000° F. the austenite is only partly transformed at the time the bainite reaction ceases for all practical purposes, but on cooling to room temperature the remaining austenite changes to martensite with a consequent increase in hardness.

As another example of the significance of the differences in mode of austenite transformation

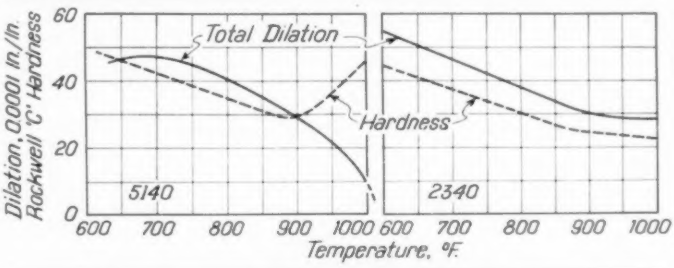


Fig. 7 — Isothermal Transformation of Two Steels at Different Subcritical Temperatures, as Characterized by Total Dilation and Rockwell Hardness (Troiano)

in the nickel steel and in the chromium steel, the following may be cited: When transformed isothermally at 775° F., the nickel steel gave a Rockwell hardness of C-33 with 100% bainite, while the chromium steel transformed isothermally at 825° F. gave the same Rockwell hardness but its structure contained roughly one third fresh martensite, the balance bainite. (The fresh martensite represented that portion of the austenite that did not transform at 825° F., but did transform on subsequent cooling.)

It may be concluded that the true hardenability of these steels is not the same as would seem when only the hardness patterns obtained on end quench test bars are studied. However, while the isothermal decomposition of austenite

*These statements can of course be verified by drawing a horizontal at 935° F. on the isothermal transformation diagram for S.A.E. 2340 in Fig. 6, and noting the times corresponding to the intersection of this horizontal with the curves plotted there.

has been widely accepted as an indication of what happens during practical hardening, direct experimentation is more convincing. It should provide additional evidence that like hardness patterns in end quench test bars do not necessarily mean like structures, and therefore like properties.

Notch Properties of Steels With Similar Hardness in End Quench Bars

Parts of the end quench bars of each of the three steels just described were subjected to X-ray examination at intervals along the length to estimate the amount of retained austenite. The results of these examinations (which were all carried out by A. R. Troiano), while qualitative and dependent upon the interpretation of the observer, clearly indicated essential differences. A graphical summary (Fig. 8) was prepared by the author from Troiano's data.

Taking the results as a whole, the nickel steel and the manganese steel retained more austenite than did the chromium steel when cooled at given rates. The differences were relatively larger under intermediate quenching rates (slack quenching conditions, represented by zones 1 in. or more from the quenched ends of the test specimens) than when the cooling exceeded the critical rates for full hardening. Likewise, the slack quenched areas had much more austenite than was found in the fully hardened zones nearer the quenched ends.

As shown previously in Fig. 5, the hardness patterns along the end quench test bars were substantially the same in the three steels under discussion (within plus or minus 1 to $1\frac{1}{2}$ points on the Rockwell C scale) yet equal hardness did not insure like structures with respect to the retained austenite. If the presence of different amounts of austenite is accepted as having an influence on the mechanical properties of quenched steels at cooling rates both above and below the critical, it follows that the mechanical properties need not be comparable in different steels with similar end quench hardness patterns.

Obviously, this point deserves more detailed investigation both with respect to the range of cooling rates represented in slack quenching and those cooling rates above the critical.

The conditions described for different positions along the length of end quench test bars are comparable to those found in the continuous cooling of specimens of different sizes, as is shown by comparing the data in the upper half of Fig. 8 with those in the lower half.

To get some idea of what this structural difference means in terms of notch toughness, Charpy test specimens of each of the three steels were quenched in oil; others were quenched in brine. They were tempered at 300° F., notched and tested. (Preliminary conditioning treatments comprised normalizing from 1650 to 1700° F., followed by a stress relief anneal and partial spheroidization by a 4-hr. heat at 1200° F., subsequently furnace cooled.)

Following the quench, duplicate brine quenched samples were subjected to liquid air exposure alternating with boiling in water, cycles designed to transform as much as possible of the retained austenite. Five low-temperature 30-min. exposures each were followed by boiling for 15 min. in water and thereafter cooling to room temperature.

In considering the results of Charpy tests on these bars, attention will first be directed to the samples merely tempered at 300° F. (not refrigerated and boiled). Tempering at 300° F. comprises a stress relief, but it will not decompose retained austenite or soften the martensite. As is shown in Fig. 9 (p. 514) the best notch properties in such samples were developed by the oil quenched nickel steel. Examination of the micrographs at the top of the chart shows that this is the only steel which, as-quenched in the Charpy bar section size, was

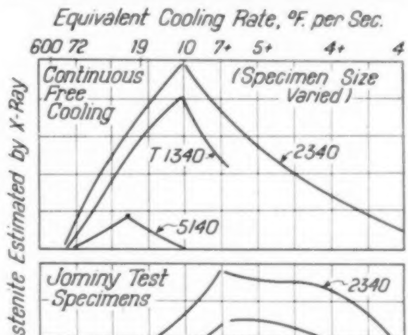
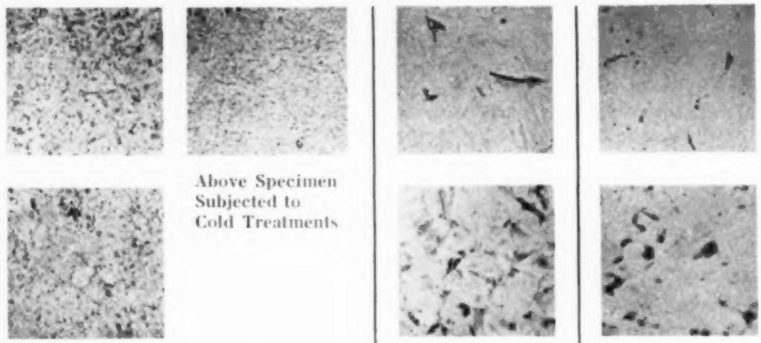


Fig. 8 — Retained Austenite Along the Length of End Quench Hardenability Test Specimens, and in Quenched Steel Samples of Different Sizes, Plotted as a Function of the Cooling Rate at 1300° F. (Plotted From Troiano's Results)

Brine Quenched Specimens in This Row

Oil Quenched Specimens



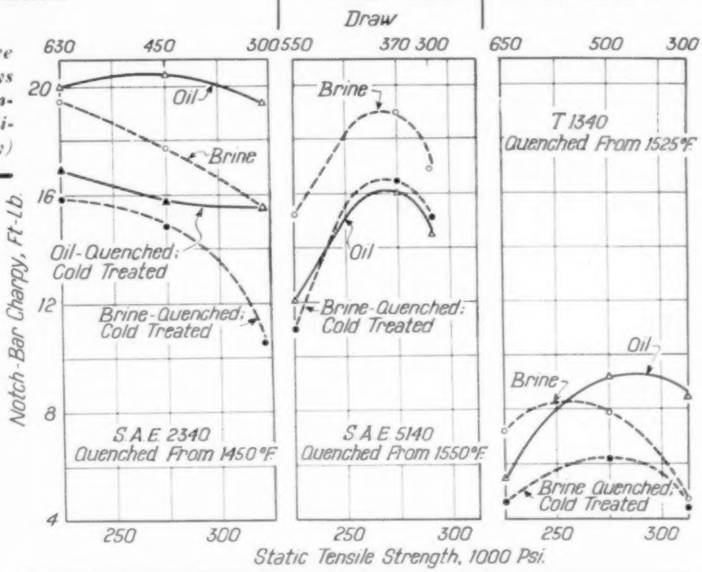


Fig. 9 — Notch Properties of Three Steels Quenched in Different Ways and Tempered at Different Temperatures and Corresponding Microstructures at 500 ×. (Brophy)

completely martensitic (other than some retained austenite). It had no lower decomposition products.

The notch-bar properties of the oil quenched nickel steel were superior to those of the same steel brine quenched and tempered at 300° F. While no direct determinations of amount of retained austenite were made on these samples, it is a reasonable assumption, based on known effects, that the brine quenched specimens had smaller amounts of retained austenite than did the oil quenched samples. Since the two major differences, structurally, are in the retained austenite and in the condition of stress — which itself is dependent on austenite — it may be concluded that notch properties are improved, within limits, by increasing the austenite content in steel quenched at rates above the critical.

This view is also substantiated by comparing samples refrigerated before tempering with those not so handled. Conversion of some, if not a major part, of the austenite to alpha iron by cold treatment reduced the notch-bar values, whether samples were first oil hardened or brine quenched.

The deleterious effects of intermediate temperature transition structures on the notch-bar properties of quenched steels is illustrated by the data plotted for chromium steel. As was shown earlier, this steel retains much less austenite than the nickel steel or the manganese steel. The micrographs at the top of the chart show that there was much more bainite (dark etching constituent) when this steel was cooled in oil than after the more rapid brine quench. The lower notch values for the oil quenched samples may then be ascribed to the deleterious effects of this larger proportion of intermediate temperature transformation products. Presumably, this effect is strong enough to counteract the benefits of retained austenite, because in this steel, as in the nickel steel, exposure to low temperatures for reduction of austenite resulted in an appreciable deterioration in notch-bar values.

Finally, it must be concluded that the *composition* of the martensite (in addition to its carbon content) contributes in an important degree to mechanical properties. This conclusion is warranted because the manganese steel (which, when oil quenched, has the benefits of a large amount of retained austenite) showed notch values much inferior to either the chromium or the nickel steels with respectively less and more austenite.

Summary of Conclusions

From these different illustrations the conclusion is inescapable that the selection of steels solely on the basis of the usual hardness test patterns in hardenability tests may be an inadequate procedure where the optimum performance qualities are essential or desired.

The successful commercial use and general acceptance of such hardening tests may be due in part to the fact that optimum properties often are not required with current machine designs. This view derives credence from the fact that, of numerous alloy steel parts taken from production heat treatments just after the quench, a majority were not fully hardened in the areas subjected to highest working stresses and, therefore, did not provide after tempering the best notch properties indicative of toughness, or resistance to brittle breaks under multi-axial service stresses. If inferior properties are adequate, a refined hardenability test itself should not be needed.

The end quench test in its present form is still one of the most convenient devised. But it crowds the greatest variations in cooling rates within a short distance of the quenched end; hence it is not especially well suited to determine critical cooling rates or full martensitic hardenability. Possibly some modification in specimen shape, not yet adequately studied, would provide the means whereby the end quench test might more certainly determine critical cooling rates, when such information is needed.

The several alloy steels discussed in the foregoing pages all showed inferior properties *when slack quenched* as compared to the fully hardened condition, but there would appear to be differences in the *extent* of the deterioration dependent upon steel composition which deserve further study.

The three alloy steels, S.A.E. 2340, 5140 and T1340, when quenched at rates *above the critical*, and only slightly tempered, developed notch-bar properties which varied with the amount of retained austenite. Within the limits studied, the highest austenite produced the best properties.

The martensite and retained austenite of fully hardened steels, only slightly tempered, varied in notch strength and toughness with the chemical composition of the steel. Much higher notch values were observed in a $3\frac{1}{2}\%$ nickel steel than in a 2% manganese steel having like hardness patterns in end quench tests and a similarly large proportion of austenite retained on quenching.

It would seem to me that the opinions expressed above are not essentially at variance with the way in which most metallurgists now view hardenability and its testing, but I hope the data presented may help to define some of those interpretations which are either not justified or which may be misleading because they have not considered all of the metallurgical factors.

Nominating Committee

IN ACCORDANCE with the Constitution of the American Society for Metals, President HAROLD K. WORK has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), treasurer (for two years), and two trustees (for two years each). This committee was selected by President WORK from the list of candidates submitted by the chapters. The personnel is:

A. L. BOEGEHOLD, General Motors Corp., Research Laboratories Div. (Detroit Chapter); chairman.

N. B. BROWN, Dept. of Mines & Resources of Canada (Ottawa Valley Chapter).

A. W. DEMMLER, Campbell, Wyant & Cannon Foundry Co. (West Michigan Chapter).

W. J. HARRIS, Studebaker Corp. (Notre Dame Chapter).

O. J. HORGER, Timken Roller Bearing Co. (Canton-Massillon Chapter).

L. K. JETTER, Oak Ridge National Laboratory (Oak Ridge Chapter).

L. W. OSWALD, Carnegie-Illinois Steel Corp. (Pittsburgh Chapter).

W. A. PENNINGTON, Carrier Corp. (Syracuse Chapter).

DANA W. SMITH, Research Laboratory, Permanente Metals Corp. (Inland Empire Chapter).

THIS COMMITTEE will meet during the third full week in the month of May. The members will welcome suggestions for candidates, in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but any individual member of a chapter may suggest to the nominating committee any candidates he would like to have in office. Endorsements may be sent in writing to the chairman or any member of the committee.

PERSONALS

Frank T. Sisco, director of Alloys of Iron Research, has been appointed technical director of the Engineering Foundation. He will continue to direct Alloys of Iron Research as well.

E. F. Houghton & Co. announces that **R. J. Rathbone** has been named field representative in the Cleveland area.

Alexander L. Feild of the Rustless Division of Armco Steel Corp. has been awarded an honorary degree of Doctor of Science by Stevens Institute of Technology for his achievements in the field of science, including the invention of the "Rustless process" of stainless steel melting.

The Heppenstall Co., Pittsburgh, announces the appointment of **S. J. Mergenhagen** to the position of sales manager. He has been with the company since 1945, representing Heppenstall in the Pittsburgh and Philadelphia areas.

National Research Corp., Cambridge, Mass., announces that **Robert A. Stauffer** as been elected vice-president and director of research. He has been associated with the company since 1942.

Livingstone Engineering Co., Worcester, Mass., announces the election of **Bradley C. Higgins**, formerly assistant to the president, to the position of vice-president and purchasing agent.

H. H. Chiswik is now associated with the Argonne National Laboratory, Chicago, Ill. Dr. Chiswik was formerly research metallurgist for the Air Reduction Co.

Ampco Metal, Inc., Milwaukee, announces that **Stuart C. Lawson** has been promoted from assistant general sales manager to general sales manager. Mr. Lawson joined Ampco in 1938 as a sales engineer and was appointed assistant sales manager in 1945.

Carl Haertel has been appointed foundry superintendent of the Falk Corp., Milwaukee. He has been with the company since 1924 and has been assistant foundry superintendent for the past 10 years.

James C. Butler has recently been transferred from the South works, Carnegie-Illinois Steel Corp., Chicago, to the U. S. Steel Research Laboratory at Kearny, N. J.

E. J. Ramaley, formerly consulting engineer and technical photographer of Columbus, Ohio, has become tool design research engineer with the Lockheed Aircraft Corp., Burbank, Calif.

The Ziegler Steel Service Co. has appointed **William Smiley**, formerly sales manager of Ducommun Metals & Supply Co., to handle sales in San Diego County, Calif.

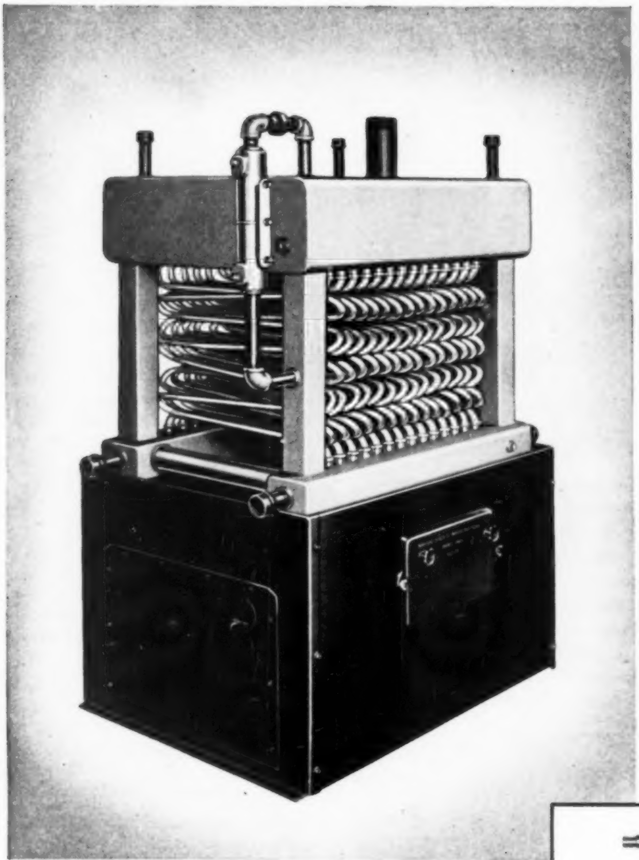
Ray H. Myers was recently appointed chief metallurgist at Willys-Overland Motors, Inc., Toledo, Ohio.

Illinois Tool Works announces that **Edward D. Wiard** has been appointed to represent the company in the Detroit territory.

Colorado Fuel and Iron Corp. announces the appointment of **Alwin F. Franz** as executive vice-president of the corporation and its subsidiaries. Mr. Franz joined the company in 1945 as vice-president in charge of operations; **Jay J. Martin**, works manager of the Pueblo plant, has been appointed to succeed Mr. Franz in his previous position.

COPPER TUBE

A VITAL FEATURE OF BRYAN BOILERS



Bryan Steam Boiler with housing removed, showing copper tubes. Bryan claims 75 pounds of steam in 15 min. from cold start, due to high heat conductivity of the Revere tubes. Also made in low-pressure and hot water models.

THE big feature of the boilers made by the Bryan Steam Corp., Peru, Indiana, is that they use copper tubes. Another important item is engineered design to meet the requirements of the fuel, whether gas or oil. Let Bryan tell the story:

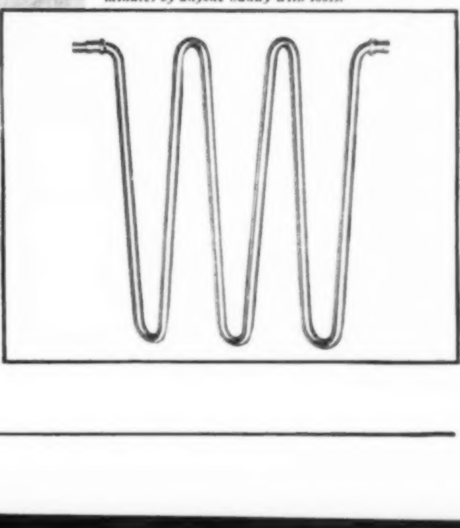
"The Bryan Copper Tube Boiler was started with a double-barreled idea. The first part of the idea was that boilers could be made more efficient by using copper tubes. Copper transfers heat many times as fast as cast iron or steel. Heat from a fire is transferred through copper tubes to water in record time, and in a Bryan Boiler with minimum heat loss through the flue due to the design.

"The second part of the idea was that if a boiler could be engineered expressly for gas or oil, the economy of operation would be such as to revolutionize the heating industry."

The first Bryan Boilers were a sensation when offered over 20 years ago. Today they are made in a number of sizes, from domestic types to 50 hp high-pressure units for industrial uses. Revere Copper Tube is used.

This is another illustration of a favorite Revere statement: "Copper is the metal of invention." Revere makes not only several types of copper tube, but also other copper and copper alloy mill products, and will be delighted to collaborate with you in such matters as selection of the most suitable metal, and fabrication methods to be employed.

Revere copper tube as fabricated by Bryan for boiler use. It is explosion-proof, because should it give after long service, water and steam escape harmlessly. A new tube can be installed in a few minutes by anyone handy with tools.



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PERSONALS

Wm. T. De Long, formerly chief metallurgist of Induction Heating Corp., is now in the technical service section of the electrode division, McKay Co., York, Pa.

After graduating from Penn State College, **M. Byron Shumaker** has joined the Aluminum Research Laboratories, New Kensington, Pa., as a research metallurgist in the chemical metallurgy division.

Albert G. Haynes is now assistant to the electrical superintendent of Mathieson Alkali Corp., Lake Charles, La.

Stan W. Moulding has formed International Consulting Engineers & Purchasers, Washington, to specialize in foreign mining and industrial enterprises.

Kenneth L. Morris, formerly general superintendent, Canada Wire & Cable Co., Ltd., is now associated with the Steel Co. of Canada, Ltd., in Hamilton, Ont. His new position is assistant to the vice-president.

Mary Baeyertz has been named assistant chairman of the metals research department, Armour Research Foundation, Chicago. Dr. Baeyertz, author of the recently published A.S.M. book, "Nonmetallic Inclusions in Steel", has been with the Foundation as senior metallurgist since March 1, 1947. Previously she was supervisor of research at the South works of the Carnegie-Illinois Steel Corp.

Vincent J. Coppola, formerly with the National Bureau of Standards, has accepted a position as instructor of metallurgy at Iowa State College, Ames, Iowa.

Max C. Farmer has recently been appointed assistant chief of the metal working division, Aluminum Research Laboratories, New Kensington, Pa.

James B. Stein is now cost analyst with the research and materiel section, Procurement Division, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.

Frank L. Wright has been appointed plant manager of the Norma-Hoffmann Bearings Corp., Glenbrook, Conn. Mr. Wright has been with the corporation since 1932, when he was appointed chief metallurgist. He has been assistant plant manager since May 1948.

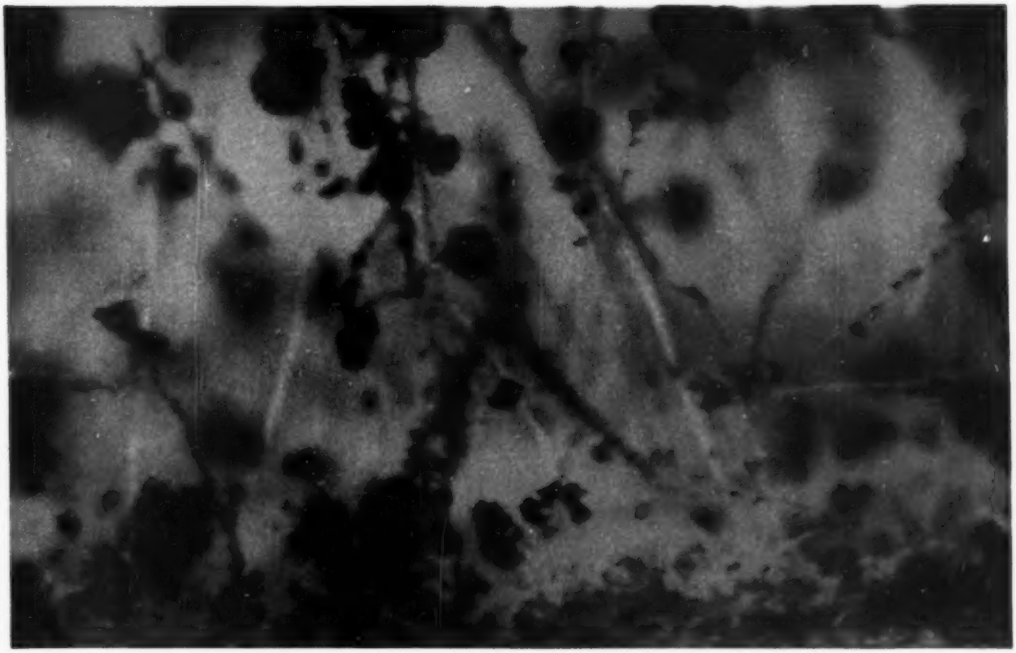
Liquid Glaze, Inc., Lansing, Mich., announces the appointment of **John T. Ott** as supervisor of its technical division. Mr. Ott was previously chief chemist of the Kaiser-Frazer Corp.

Clyde R. Tipton, Jr., formerly with Battelle Memorial Institute, has joined the staff of the chemistry and metallurgy division of the Los Alamos, N. M., Scientific Laboratory of the University of California.

After graduating from Purdue University, **Donald F. Currier** joined the metallurgical department, Inland Steel Co., East Chicago, Ind.

James E. Brown, formerly process engineer with the Carnegie-Illinois Steel Corp., has been promoted to claims and investigation metallurgist of the Duquesne works, Pittsburgh.

Michael L. Monack has been transferred by E. I. duPont de Nemours & Co., Inc., from the Spruance plant, Richmond, Va., to the Wilmington office where he will be engineering materials consultant in the engineering department.



An example of Aspergillus Niger or "Blue Mold"—a common mold magnified seventy times

PERSONALS

John E. Seward, formerly with Wisconsin Steel Works of International Harvester Co., is now with Jones & Laughlin Steel Corp. as a blast furnace practice engineer at the Pittsburgh works.

H. B. Goodwin, formerly with the Kellex Corp., Silver Spring, Md., has joined the staff of Battelle Memorial Institute, Columbus, Ohio, as a research engineer.

Charles Elson is now a metallurgist at the industrial laboratory, Mare Island Navy Yard, Vallejo, Calif.

James H. Cooper has been elected vice-president in charge of engineering of the McCord Corp., Detroit. He has been with the company since 1910 and has been works manager since 1935.

Joseph J. Warga, formerly a development engineer at the Kimble division of Owens-Illinois Glass Co., has rejoined the Sperry Gyroscope Co., Great Neck, N. Y., as nonferrous standards engineer.

After graduating from Virginia Polytechnic Institute, **James A. Steele** has joined the General Electric Co. and is at present participating in its training program.

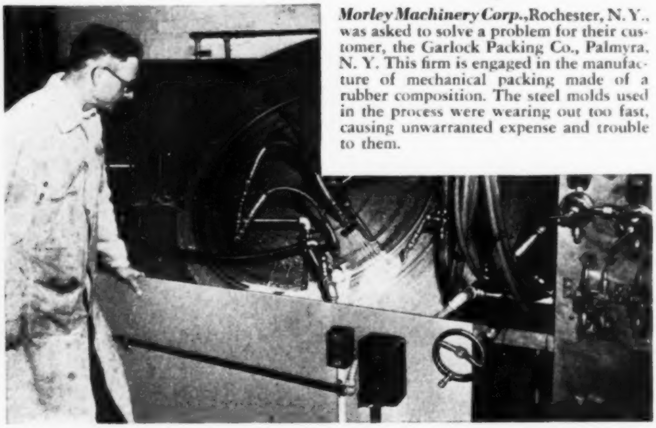
E. E. Alpers joined the central foundry division of General Motors Corp. as a metallurgist on graduation from the University of Illinois.

G. M. Snyder has been appointed vice-president and executive metallurgist of Woodings-Verona Tool Works, Inc., Verona, Pa. He joined the company 1½ years ago as executive metallurgist, having previously been metallurgist for Carnegie-Illinois Steel Corp.

W. E. McKibben, formerly with Alloy Engineering and Casting Co., Champaign, Ill., has joined the staff of operations research office, Dept. of Army, Ft. Leslie J. McNair, Washington, D. C.

Ernest G. Kendall has been appointed instructor in metallurgical engineering at the Polytechnic Institute of Brooklyn, N. Y.

Arthur M. Lennie, formerly industrial consultant for the University of Wichita Research Foundation, has been appointed to the marketing and development division of Armco Steel Corp., Dayton, Ohio.



CLEANING ALUMINUM SHEET

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8. "Investigation of the Final Rinsing Operation in the Chemical Surface Preparation of Alclad 24S-T for Spot Welding"; by R. A. Wyant, D. J. Ashcraft, and T. B. Cameron. Progress Report on Aircraft Spot Welding Research to Office of Production, Research, and Development, War Production Board, Contract No. WPB-193; April, 1945. This report was also published in *Welding Research Supplement to Welding Journal;* V. 24; July, No. 7; (1945); p. 361-s to 369-s.

(Continued on p. 524)

CLEANING ALUMINUM SHEET

(Continued from p. 522)

9. "Report to the Members of the Aircraft Welding Research Committee". Armstrong Cork Co., Lancaster, Pa.

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11. "An Investigation of Spot-Weld Test Specimens. Part I — Comparison of Specimen Types and Dimensions Alclad 24S-T 0.020, 0.040, 0.064 Inch in Thickness"; by W. F. Hess, R. A. Wyant, and B. L. Averbach; *Welding Research Supplement to Welding Journal;* V. 21; March, No. 3; (1942); p. 113-s to 119-s.

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LOW-TEMPERATURE PROPERTIES OF Al*

THE AUTHORS investigated the mechanical properties of high-purity aluminum (0.11% Si) and two aluminum alloys, apparently of commercial production. One alloy contained 2.8% Mg and 0.37% Mn, the other 2.29% Mg and 2.04% Mn. The test specimens were all of round section, taken from rolled material. Tensile tests were made at three temperatures: +68, −76 and −297° F. Fatigue tests were run at +68, −67, −102 and (for pure aluminum) −256° F. Tensile data included the yield strength at 0.2% elongation, true stress and actual strain up to the point where necking started, ultimate tensile strength, final deformations, and true stress at fracture. The latter was determined in tension-impact tests on notched specimens.

Low temperature has slight effect on the yield strength. Down to −76° F. it does not greatly affect the resistance to further plastic deformation, but at −297° F. that resistance rises rapidly. For the 3% Mg alloy the homogeneous reduction in area — about 15% — is not affected by temperature.

Three diagrams show the effects of temperature on tensile properties. The final reduction in area of pure aluminum remains constant; other characteristics increase as the temperature decreases. For the 3% Mg alloy, the tendency to uniform plastic deformation does not increase, while the final reduction in area increases to −76° F. and decreases to −297° F. Strength characteristics increase at an accelerated rate.

Three S-N diagrams show that the fatigue limit hardly changes by as much as 10% (13,000 to 14,000 psi.) between +68 and −102° F. for the two alloys. For pure aluminum, the fatigue limit apparently remains low (less than 5000 psi.) at all temperatures down to −256° F.

Most important in this paper is the description of the apparatus, which is rather ingenious and probably could be used at even lower temperatures. The source of the cold was liquid air and the test specimens themselves were sur-

(*Continued on p. 528*)

*Abstracted from "Testing Metallic Materials at Low Temperature", by Karl Wellinger and Artur Hofmann, *Zeitschrift für Metallkunde*, Vol. 39, 1948, p. 233.


WE HAVE THE KNOW-HOW
PLUS THE KNOW-WHEN-NOT-TO
It is know-how, gained by diversified product experience and research, that equips us for the quantity production of top quality metal powder parts.
Just as important as knowing *how* to apply the art of powder metallurgy is to know when *not* to. That knowledge leads us to refuse orders to produce any part that cannot be made advantageously and economically by the metal powder process.
Of course, we gladly accept orders for items that meet our three basic requirements for efficient production:
• The shape must permit good die fill and proper density.
• The required physical properties and tolerances must be within the range obtainable in normal factory production.
• The quantity ordered must be sufficient to justify the initial tooling costs.
What we mean is . . . we accept orders only when we know that the customer will be sure to obtain lasting satisfaction.
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DIVISION OF GENERAL MOTORS, DAYTON, OHIO

LOW-TEMPERATURE PROPERTIES OF Al

(Continued from p. 526)

rounded by a noncorrosive organic mixture that remained liquid at the temperature of the test and would not evaporate rapidly even at room temperature.

Unfortunately, no tables were published and it is impossible to judge whether the data were averages of a number of tests or the results of single tests — 18 tensile and 56 fatigue tests.

The authors make a theoretical excursion into the relations among crystal structure, mechanical properties and temperature, taking zinc, aluminum, copper and iron as a basis for generalizations. Their sketches look quite appealing, but it might be well to remember that great differences exist among beryllium, titanium, magnesium and zinc (all hexagonal), between copper and rhodium or iridium (all face-centered cubic) and between iron and sodium or tungsten (all body-centered cubic).

PEARLITE*

THIS is a continuation of an earlier article, which was a general study of the crystallization of eutectics. In this latest paper, the author used for the original mass a single grain of austenite transforming to pearlite. To simplify the mathematics, the transformation is idealized to a "stationary" process with a plane reaction interface. After making a number of assumptions, the author obtains four differential equations having five unknowns and twelve numerical coefficients.

It would have been worth the trouble to carry through the involved computations if the results had been in agreement with the known magnitudes. But the author has to state that his maximum computed velocity is probably about 100 times too small, and this discrepancy cannot be attributed to errors in the measured values of transformation velocity or inter-

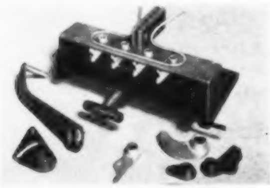
(Continued on p. 530)

*Abstracted from "Calculation of the Velocity of Eutectic Crystallization, Illustrated by the Example of Pearlite", by Erich Scheil, *Metallforschung*, Vol. 1, 1946, p. 123.

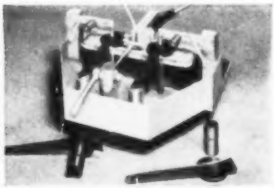
This fixture brazes caps on seamless tubing to form 200 dashpots per hour, at 1/5 the previous cost. They were formerly deep drawn.

15 DIFFERENT PARTS BRAZED AND ANNEALED BETTER, FASTER, CHEAPER

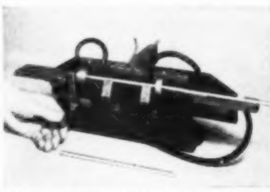
using ONE Westinghouse 5-KW RF Generator



Bushings are brazed on six different cam assemblies and crank arms with this fixture—production rate 160 per hour.



This water bath fixture brazes the hollow shaft to the arm without annealing the hardened key on the end of the shaft, at 200 per hour.



This fixture selectively anneals three points—later drilled—on a hardened shaft at 800 per hour. Two different shafts are handled by adjusting the coil positions.

New proof of the amazing versatility of Westinghouse RF heating is given by production data from the Victor Adding Machine Company. At their Chicago plant, 15 different parts are now being brazed or annealed using a single 5-kw Westinghouse RF generator and four quickly interchangeable fixtures.

Very substantial savings and greatly increased production rates are resulting from their use of this up-to-the-minute production tool. Brazing operations are cleaner and without distortion. This localized heating—inherent with RF heating—is used to advantage in brazing these parts without annealing adjacent hardened areas. And from an over-all standpoint, they report these four big advantages:

1. **Simplification of assemblies**
2. **Reduction in number of operations**
3. **Elimination of detailed inspection, formerly required**
4. **High output of good quality, using unskilled operators.**

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PEARLITE

(Continued from p. 528)

lamellar distance. The author concludes that the diffusion velocity must be considerably higher at the reaction interface than in an undisturbed crystal.

The author then presents a hypothesis for transformation, according to which the original austenite will transform first into two transitional austenites, one of low carbon content, the other of high carbon content. These will, in turn, transform to ferrite and cementite respectively. The author states that such a process may be applicable to the intermediate (bainite) reaction in alloy steels. [A similar, more explicit mechanism for bainite formation has been proposed by E. P. Klier (*Transactions*, A.I.M.E., Vol. 158, 1944, p. 394; and Vol. 162, 1945, p. 186).]

IMPACT OF 25% Cr-Fe*

THIS very brief report contains a documented statement of great importance: Low-carbon 25% Cr iron can be improved markedly by vacuum remelting. In the quench annealed condition, an alloy having originally an impact strength of 1 m-kg. per sq.cm. developed a strength of from 28 to 34 m-kg. per sq.cm. (probably equivalent to an Izod value of at least 150 ft-lb.) by remelting in a vacuum (0.001 mm. of mercury) to eliminate most of the carbon, oxygen and nitrogen.

Chemical compositions before and after vacuum remelting were:

	Before	After
Carbon	0.035	0.005
Manganese	<0.005	<0.005
Chromium	25.2	24.9
Sulphur	0.005	0.005
Oxygen	0.060	0.002
Nitrogen	0.058	0.002

Recarburizing to 0.035% C reduced the impact resistance to 1.28 m-kg. per sq.cm., and after nitriding to 0.21% N the impact strength was 11.6 m-kg. per sq.cm., a reasonably good value but much lower than that of the purer alloy.

It is interesting also that the vacuum melted alloy could be forged to a reduction of 75% even though no manganese was added.

*Abstracted from "Improvement of the Impact Resistance of Ferritic Alloys Containing 25% Chromium by Vacuum Melting", by J. Hochmann, *Comptes Rendus*, Vol. 226, 1948, p. 2150.

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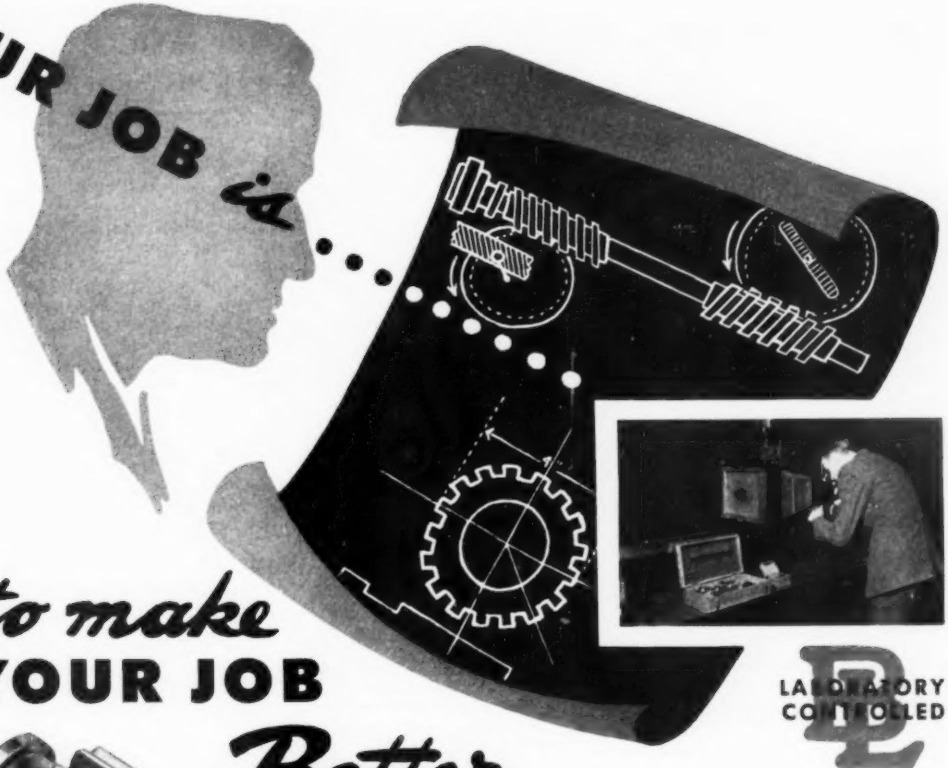

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PARTICLE SIZE OF TUNGSTEN POWDER*

IF A fine grain size is required in cemented carbide products, the raw materials must have a small particle size and each stage of manufacture must be planned to inhibit grain growth. It is necessary to have, thus, an accurate and rapid method of determining particle size distribution if the quality of "hard-metal" products is to be controlled on a production scale. From this point of view, the authors have investigated methods of determining particle size distribution and have also studied variations in particle size in the various stages of manufacturing cemented carbides from the original tungstic oxide through to the sintered alloy.

The methods investigated were *(a)* the sedimentation balance; *(b)* the Richardson turbidimeter; *(c)* a gross method employing the Spekker absorptiometer, which gives a value for the specific surface; *(d)* optical microscopy at 1500 diameters; and *(e)* electron microscopy at 5000 diameters.

In all the methods, the difficulty of completely dispersing the particles was a primary cause of error. It was concluded, in this connection, that determinations by optical microscopy could not be used as a standard; all that could be done was to standardize conditions to obtain reproducible results. Because of these aggregates of particles, none of the methods alone is suitable for accurate size distribution measurements on tungsten powders. The most promising rapid method seems to be an improved turbidimeter, coupled with a greater knowledge of aggregation and sedimentation phenomena and of the absorption of light by particles.

For the interim, a determination of the surface area by the Spekker instrument was adopted for measuring particle size, supplemented by optical microscopic examination for shape and size range. Both the Spekker method and the turbidimetric method suffer from an insecure theoretical foundation, yet for the types of powders examined, both appear to give the correct order of size over the range 0.1

(Continued on p. 534)

*Abstract of "The Measurement of Grain Size of Tungsten and Tungsten Carbide Powders Used for the Manufacture of Hard Metal", by H. Burden and A. Barker, *Journal*, Institute of Metals, Vol. 75, 1948, p. 51.

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PARTICLE SIZE OF TUNGSTEN POWDER

(Continued from p. 532)

to 10 microns. The Spekker method has a further disadvantage that only the specific surface is measured. The fact that a complete determination can be made in 10 min., however, is believed to more than outweigh these disadvantages.

The results show how tungsten behaves during processing. The four types of powder, having specific surfaces of 322, 1760, 4720 and 14,500 sq.cm. per g., respectively, were converted to tungsten carbide and sintered with 6.25% cobalt, under conditions chosen separately for each powder to give the highest hardness. The hardnesses achieved were Rockwell A-88.3, 90.8, 91.2, and 91.7, increasing as the powder became finer. The hardness obviously depends on the particle size.

While the investigation was in progress, large quantities of the four types of tungsten powder were used for production work, and their behavior was consistent with the laboratory results. The method, thus, can be recommended for control of hardness in production and for allocating batches of powder, since it appears that a useful parallelism between hardness of cemented carbides and the surface area of tungsten carbide powder (as well as the original tungsten powder) has been established.

NITRIDING*

THE ARTICLE begins with a general examination of nitriding. The rate of nitrogen absorption increases with the temperature but must be kept at a comparatively low figure lest nitrides of iron begin to predominate. Iron nitrides form locally and grow rapidly, embrittling the surface without increasing the hardness.

To obtain a layer 0.5 mm. thick, 30 hr. is required at 1040° F. and from 70 to 100 hr. at 970° F. However, because of the danger of forming iron nitride, the process must be run between 900 and 970° F., and only a shallow case can be obtained in a commercially feasible time. An

(Continued on p. 536)

*Abstracted from "Nitriding", by H. Wiegand, *Revue de Métallurgie*, 1948, p. 105-118.

NITRIDING

(Continued from p. 534)

ionized atmosphere stimulates the nitriding process but the author gives no detail about the methods of producing such an atmosphere and the results obtainable.

In a shallow layer the hardness obtainable in chromium-aluminum steels is considerably higher than in chromium-vanadium steels, but the difference is not so great in thick layers.

Besides the definite advantage gained because of the high wear resistance of the nitrided layer, nitriding is advantageous in increasing the corrosion resistance of ordinary and low-alloy steels in water and humid air. It has the opposite effect on stainless steel. The advantage gained in fatigue resistance is much greater. Nitriding produces a compressive stress in the outer fibers of steels, and for this reason the maximum tensile stress under alternating load is lowered considerably. A more nearly uniform stress distribution toward the neutral axis results. The fatigue limit is raised by 28 to 55% for unnotched specimens and by 64 to 130% for notched specimens of various steels. The S-N curve is shallower and the damage region greatly narrowed. Steels containing molybdenum in addition to chromium and vanadium (no aluminum) show a greater fatigue resistance when nitrided and are somewhat less sensitive to shock.

Nitriding is particularly beneficial where rotating parts of heavy machinery are subjected to gripping, which causes the formation of a finely disintegrated layer of metal that oxidizes rapidly. With ordinary steels this can be prevented only by a high polish of the surface after heat treating. Nitrided steels need not be polished; they can be used as received.

The main drawback to nitriding is that the steel is sensitive to shock in transportation and during installation. If fissures form they can be counteracted somewhat by repolishing the damaged part or by repolishing followed by another nitriding.

Finally, the author examines specific parts for which nitriding is of great advantage and also some where it has a negative effect. Nuts and other threaded surfaces are examples of those that should not be nitrided, because the sharp corners are likely to be too brittle.


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THE ORIGIN OF INTERNAL STRESSES

THE eleven papers reviewed here constitute Section II, Part *(a)* of the "Symposium on Internal Stresses in Metals and Alloys", published by the Institute of Metals, London, 1948. The first section of this symposium (Measurement of Internal Stresses) was discussed in the February issue of *Metal Progress*, p. 242.

The first paper in Section II, by E. Orowan, considers the classification and nomenclature of internal stresses.* He suggests that we talk about body stresses and texture stresses, instead of macrostresses and micro or tessellated stresses, because macro and micro do not properly define the situation, and tessellated is rather awkward.

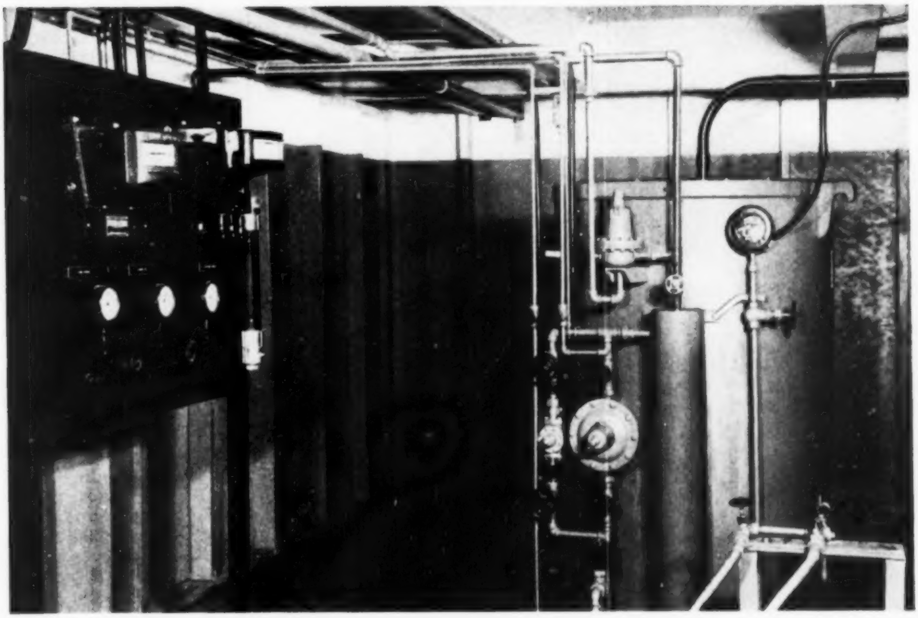
Most of Dr. Orowan's discussion refers to texture stresses, whereas the metallurgist is interested principally in the body stresses. Orowan divides the texture stresses into six groups: those caused by incomplete gliding and by kinking (a theoretical conception), those caused by variable grain orientation, boundary stresses between the grains, martensitic transformation stresses, precipitation stresses, and thermal stresses between constituents as a result of unequal expansion or contraction.

F. R. N. Nabarro reviewed four theoretical papers on "tessellated" stresses published by F. Laszlo in the *Journal* of the Iron and Steel Institute. Such stresses change from grain to grain and even within individual grains. The review begins with the statement that such stresses may appear even in annealed cubic metals while the applied stress is still within the limit of elasticity, because the modulus of elasticity varies from one direction to another. But, in this reviewer's opinion, the important thing is the limit of elasticity, and this has scarcely ever been investigated in relation to the crystallographic direction of the applied stress. At any rate, it is stated (on theoretical grounds) that such stresses might amount to 35% of the applied stress.

Of more interest are Laszlo's

(Continued on p. 540)

*Editor's Note: While on the subject of nomenclature, we may note the British preference for the term *internal stress*, which, according to the 1948 ⓐ Metals Handbook, p. 8, is a "misnomer for *residual stress*".



A Drever Ammonia Dissociator and instrument panel as installed in a large radio tube factory. The dissociator component consists of an electrically heated vertical cylindrical furnace, enclosing a fabricated Inconel retort which contains a catalyst.

THE ORIGIN OF INTERNAL STRESSES

(Starts on p. 538)

ideas — rather incompletely reproduced by Nabarro — regarding intergranular stresses in polyphase systems and within grains carrying a precipitate or forming a colony (pearlite). It is, however, a purely mathematical examination based on rough assumptions and operating with constant and isotropic elasticities against differences in thermal expansion. Here the review of Laszlo's computations becomes too brief and unsystematic to permit further abbreviation.

Very few figures of the magnitudes of the possible stresses are reproduced and the probability of these figures being correct is not discussed. The reader must repair to the original papers by Laszlo and to the other papers given in the bibliography in order to get a fair understanding of the subject.

Maurice Cook's paper on the relation of composition to stress-corrosion cracking in copper alloys (11 pages, 40 references) is a clear statement of the situation existing at the time his paper was written,* but seems out of place in the section of the monograph dealing with the *origin* of internal stresses.

The paper by H. Elliss on internal stresses in steel castings (8 pages, 19 references) deals mainly with generalities concerning the way in which internal stresses might originate in castings. Considerably more precise and instructive are his "Notes on Hot Tearing".

It is this reviewer's considered opinion that foundry researchers put too much emphasis on developing means to eliminate stresses and hot tearing, and too little emphasis on the quantitative study of the phenomena involved. It is all right to talk about the use of fillets, but the important thing is to find how great these should be to eliminate stresses. It is all right to state that the sand should not be packed too

(Continued on p. 542)

*EDITOR'S NOTE: For more recent data on this subject, the reader may consult "Influence of Composition on the Stress-Corrosion Cracking of Some Copper-Base Alloys", by D. H. Thompson and A. W. Tracy, *Journal of Metals*, Vol. 1, Sec. 3, p. 100-109 (Feb. 1949). Thompson and Tracy studied oxygen-free high-conductivity copper, tough pitch copper, and binary copper alloys containing up to 40% Zn, 0.9% P, 1.2% As, 1.0% Sb, 4% Si, 30% Ni and 8% Al.

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hard and that the cores must not be too hard either, but the real thing is to find, by systematic experimentation, how hard the sand and the cores should be for any given casting. It would not be too difficult to test the molds, cores and coupons taken from various spots in experimental castings in order to get an idea of the stresses and the hot tearing, so that the subject might be presented on a quantitative and illustrative basis.

J. E. Russell's paper on the stresses in large masses of steel cooling from the austenitic region (11 pages, 13 references), although of limited scope (eutectoid steel only), presents a clear analysis of the stresses that can arise in quenching and in austempering, and that can be calculated if the necessary physical constants (specific heat, heat of austenite decomposition, thermal expansion, modulus of elasticity and Poisson's ratio) are known for any temperature up to the eutectoid point. The temperatures themselves can be found as a function of the distance from the center by an equation involving diffusivity and the temperature-delaying effect of the transformation of austenite. This latter can be computed from auxiliary curves derived from the isothermal transformation diagrams. Ten graphs, in which the calculated stress is plotted as a function of time, indicate the relations between thermal stresses and transformation stresses in quenching and in austempering. The author states that the needed data are too poorly known and that it is a question whether ferritic steels could be analyzed in the same manner.

A. W. Hothersall's paper on stress in electrodeposited metals (11 pages, 25 references) is an original contribution relating briefly the author's experimental results with plating cobalt, copper, nickel, zinc, lead and silver on steel. It gives sketches of the six methods that can be used to determine the stress in the deposit from the deflection of the base strip. A condensed table that includes also the results of other experimenters who studied deposits of iron, chromium and cadmium seems to indicate (the author does not state it) that

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THE ORIGIN OF INTERNAL STRESSES

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the strong metals (chromium, iron, nickel and cobalt) usually develop rather high tensile stresses, while the metals of intermediate strength (copper and silver) show very small stresses, and the weak metals (cadmium, zinc and lead) develop compressive stresses. Variations in the nature of the electrolyte can apparently reduce the tensile stresses and even reverse them. The reasons for the appearance of stresses are not yet understood: none of the reasons suggested by the author is fully satisfactory. [In discussion, G. V. Raynor pointed out that, in electrodeposition, certain crystallographic planes in the electrodeposited metal will be parallel with planes in the substrate that have a similar atomic configuration. Because the matching of atoms is not exact, there is stress at the interface.]

R. Weck's paper on residual stresses caused by welding (13 pages, 6 references) gives a brief description of the results of his own investigations in welding mild steel plates. The diagrams of transverse and longitudinal strain in the restrained, released and partitioned states are quite illustrative.

"Cracking is a disruption of the continuity of the solid." An expression of this sort sounds rather scientific, but is almost meaningless. It says that cracking is cracking and nothing else.

The author assures us that residual welding stresses will hardly ever be superimposed on service stresses to the extent of limiting the applied load and that brittle failures have not been shown to result from residual stresses caused by welding. The same logic might be applied to all residual stresses. Unfortunately, residual stresses might be localized without being strictly microstresses. External loads, particularly sudden loads such as shell hits, might release such stresses by localized cracking, causing a redistribution of stress and further cracking.

F. P. Bowden and A. J. W. Moore's paper on internal stresses produced by sliding (6 pages, 6 plates, 6 references) examines the phenomena at the contact between a polished hemispherical glider point and a polished flat surface

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of metal below it. The metals were: steel on hard and on annealed copper, copper on copper, copper on steel and copper on platinum. Micro-examination of the metal under the surface of the groove indicates distortion to a considerable depth for clean metals with a very high friction factor and to a lesser degree with a lower friction factor under lubrication. The authors conclude that a localized welding occurs and that the breaking down of the joint in gliding produces a considerable stress below the surface. Good micrographs are presented, but no magnitude of the stresses is indicated.

M. C. Caplan, L. B. W. Jolley and J. Reeman's paper on internal stresses in turbine rotors (14 pages, 2 references) is an extremely brief report of their work intended to find the conditions under which a permanent set or a deflection can be expected for a given turbine wheel or shaft.* Neither the experimental technique nor the calculations leading to the establishing of stress magnitudes are described sufficiently for a metallurgist to get a clear idea of the process. The authors conclude that the residual stresses after normalizing and tempering are not sufficient for the development of a permanent set when added to the centrifugal stresses developed in service. An expression "chemical axis" is used parallel with "geometrical axis" in describing the possible effects of chemical segregation.

G. Forrest's paper on residual stresses in beams after bending (10 pages, 8 references) is a purely theoretical study of stresses remaining after the spring-back in a plastically bent beam and of their elimination by stretch bending and by reverse bending. Although the mathematics in the most elementary example of a rectangular beam is quite simple — too simple to be

(Continued on p. 548)

*Editor's Note: In the 1948 Metals Handbook, p. 241, stress relief by "overspeeding" is discussed briefly in relation to turbine wheels and centrifugal compressors. In this process, the semifinished wheel is rotated for a few minutes at a speed 10 to 15% greater than the highest speed at which it will be required to operate in service. During overspeeding, residual stresses are redistributed and reduced.

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stated — the transition to the presented diagrams of stresses is too great and is not illustrated by even the briefest table of factors used and results obtained. For a T-type beam the mathematics is presented without any table of notations preceding, which makes it almost impossible to follow the presentation, even though the accompanying diagrams are most intriguing. It is further unfortunate that, instead of applying his computations to some metal ordinarily used for the construction of members acting under bending forces, the author used a hypothetical metal with 52,000 psi. proof stress, 78,000 psi. tensile stress and 17.5% elongation. His diagram of residual stress versus radius of curvature remaining after spring-back for that metal indicates that the stress computable for any curvature short of failure must be about 27,000 psi., while in his discussion he states that the internal stress produced is limited only by the ultimate stress.

The last paper in the section on origin of internal stresses is by W. C. Hynd, and it treats the internal stresses in glassware. Although the author himself doubts whether the understanding of stresses in glass might be of value to the metallurgist, anything that happens with any kind of matter under the action of heat or mechanical stressing should be of interest to the metallurgist, unless he wants to be a narrow artisan.

What robs the paper of its possible value is its purely verbal approach to the problem of thermal stresses in glass and its acceptance of Griffiths' theory of flaws. The optical characteristics of glass are inconsistent with the presence of such flaws and the fact that a sheet or rod of glass supported as a beam will suffer a continuous plastic bending also is not in accord with the theory of flaws.

It seems to this reviewer quite doubtful whether the stresses in glass are of a thermal nature. A poor adjustment of the initial particles during the molding and forming process seems more likely to cause brittleness and the slow annealing of glass might mean a slow readjustment of structure rather than an elimination of thermal stresses.

M. G. CORSON

THE FRACTURE OF SHIP STEELS*

WHEN a steel fails in service it is usually desirable to determine the cause of the failure. To do this it is important to obtain a proper interpretation of the metal's fracture pattern together with an adequate appraisal of the service conditions existing at the time of the failure. If some small-scale laboratory test procedure could be found by which simulated service fracture characteristics of the metal could be studied, then not only could the serviceable life of the metal be predicted with greater assurance but also service failures could be understood better.

In this program of tests of ship plate the authors have used a notched bend bar and an edge-notched tension bar to determine the transition phenomena of ten ship-plate steels. The fracture characteristics of the steels in these tests are correlated, with some degree of success, with the fracture characteristics of the same steels obtained in a previous investigation using internally notched tension specimens of flat plate 72-in. wide.

The slow-bend bar used was a modified Schnadt type with the compression zone drilled out to ½-in. diameter, the hole being filled by a hardened steel pin through which the test load was applied to the bar. Thus, fracture of the bar in the slow-bend test occurred entirely through metal that was under a tensile load. The long axis of the bend specimens and that of the edge-notched tension specimens were in the direction of rolling of the ¾-in. plate. The notch of the bend bars was in the thickness direction of the plate so that, in effect, the fractures of both types of test bar were transverse to the direction of rolling of the plate. The edge-notched tension specimens were loaded through pins by means of suitable shackles.

In the slow-bend tests measurements of energy absorption were not made because, as is indicated by the authors, such measurements would normally be too costly and time consuming. Transition temperature was determined on the basis

(Continued on p. 554)

*Abstracted from "Fracture Characteristics of Ship Plate in Certain Small-Scale Tests", by E. P. Klier, F. C. Wagner and M. Gensamer, *Welding Research Supplement*, Feb. 1949, p. 50-s to 66-s.

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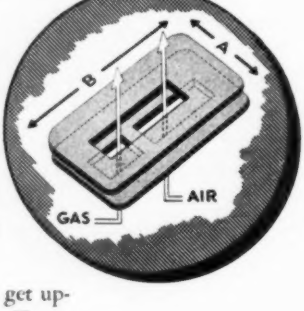

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THE FRACTURE OF SHIP STEELS

(Starts on p. 550)

of measurement of lateral contraction of the specimen at a critical cross section and also on the basis of type of fracture. Quantitative agreement of the two types of data is usually within 5° F. The fact that the transition range is easily determinable by visual inspection of the fracture surface marks this second procedure as the more convenient of the two procedures for general usage. The critical cross section found to be most reliable for measurement of lateral contraction of the test specimen was adjacent to the ½-in. diameter hole and for this measurement it was not necessary to fit the halves of the broken specimen together.

The bend test data exhibit a transition range, usually about 30° F. wide. Between the upper and lower limits the intermediate values are few in number and there seems to be no distinguishable gradation of ductile or brittle fracture between them. Of the two temperature limits, the upper is the more important and is reported as the transition temperature.

In the edge-notched tension tests, transition temperature was determined on the basis of measurement of energy absorption, lateral contraction, elongation, and evaluation of type of fracture of the test bar. The data for fracture type show a definite transition from shear to cleavage in all steels, whereas the data based on the other three measurements do not. In particular, the data for energy absorption do not always reveal a transition, but when they do, this transition temperature is noticeably lower than that indicated by the type of fracture. Thus, a noticeable energy absorption occurs during the test — even with a brittle fracture. Transition based on measurement of lateral contraction agrees quite closely with that based on type of fracture, as is true with the slow-bend test data also.

Despite the lack of correlation between the transitions indicated by energy absorption and fracture type, the latter transition is in good agreement with the results obtained from the 72-in. wide, internally-notched, flat plate tension specimens of the previous investigation. It would therefore appear that determination of transition temperature

(Continued on p. 556)

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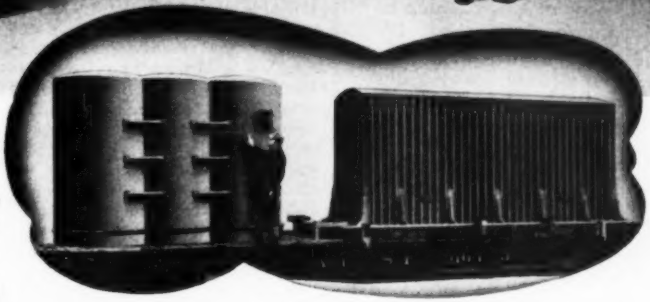

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THE FRACTURE OF SHIP STEELS

(Starts on p. 550)

by evaluation of fracture type offers a better basis than any other for correlation between various types of fracture tests and also is most convenient, since no complex apparatus or calculations are required.

In conclusion, the authors point out that the slow-bend notched-bar testing procedure using the Schnadt-type bar with a pressed notch of 0.0015-in. root radius, 45° included angle, for the most part yields satisfactory fracture data for correlation with the data from internally-notched plate 72 in. wide. Also, for the tension tests on edge-notched bars, the transition temperature determined from fracture appearance is in approximate agreement with the results obtained with plates 72-in. wide, while that determined from energy absorption is not.

The authors suggest an explanation for the discontinuity of the curves of lateral contraction and fracture type versus temperature in the slow-bend tests, by reference to Davidenkov's failure mechanism. It is suggested that a change in curvature of the cleavage failure curve in the Davidenkov diagram of mechanical failure would account for the discontinuities observed. It would also appear from the edge-notched tension data that a cleavage type of fracture under low rate of strain need not be a brittle fracture.

TENSION-IMPACT OF SHIP STEELS*

THE INFLUENCE of strain rate and temperature on the mode of fracture of metals is not a subject for simple mathematical calculation nor can it be evaluated in quantitative units for practical application. Sometimes the Charpy notched-bar test does not distinguish clearly between steels and does not give a precise determination of transition temperature. For this reason, in the test program by Bruckner and Newmark, a notched tension-impact bar was used in testing six of the ten

(Continued on p. 558)

*Abstracted from "Axial Tension-Impact Tests of Structural Steels", by W. H. Bruckner and N. M. Newmark, *Welding Research Supplement*, Feb. 1949, p. 67-s to 80-s.

TENSION-IMPACT OF SHIP STEELS

(Starts on p. 556)

ship steels studied by Klier, Wagner and Gensamer. (See p. 550.)

It is indicated that this notched tension-impact specimen was used because of certain advantages it has over the Charpy bar — for example, a uni-axial tensile stress and a uniform notch that can be varied to give any desired degree of stress concentration. The authors point out that the transition temperature obtained in tests of wide plate was determined easily by the sharp decrease in energy absorption but it was difficult to define the transition temperature from the Charpy tests because of the gradual decrease in energy absorbed.

The first part of the program was concerned with a study of the effects of specimen size and notch geometry on the shape of the curves of absorbed energy versus testing temperature. From this study, a standard specimen was evolved that had a semicircular notch of 0.039-in. radius, a root diameter of 0.294 in. and an outside diameter of 0.625 in.

In the second part of the program this standard specimen was used in testing the six steels at various temperatures to determine the change from ductile to brittle fracture as the temperature of testing was reduced. A pendulum-type testing machine was used, and tests were made with various heights of pendulum adjusted to give kinetic energies of 220, 110, 45 ft-lb., and lower. In all these tests the mass of the pendulum remained constant; hence, these variations in kinetic energy of the pendulum produced some differences of strain rate in the specimens during fracture.

Values for transition temperature (approximate midpoint of the transition range) were obtained from curves of absorbed energy per unit area at the root of the notch, reduction of area, and absorbed energy per unit area of fracture — all versus testing temperature. Also a determination of transition temperature was made based on the point where a 15% reduction in area at the root of the notch occurred. The curves of absorbed energy per unit area of fracture versus temperature exhibit less scatter in the transition range than do the other determinations, although the same trends are indicated by all of them.

(Continued on p. 560)

TENSION-IMPACT OF SHIP STEELS

(Starts on p. 556)

In the curves of energy absorption per unit root area there is more scatter, particularly in the transition range, when using 220 ft-lb. initial energy for the test than when using the lower values of initial energy. Away from the transition range, energy absorption seems to be independent of the initial pendulum energy except that a greater absorption of energy is apparent when the test specimen is subjected to barely enough energy to cause rupture.

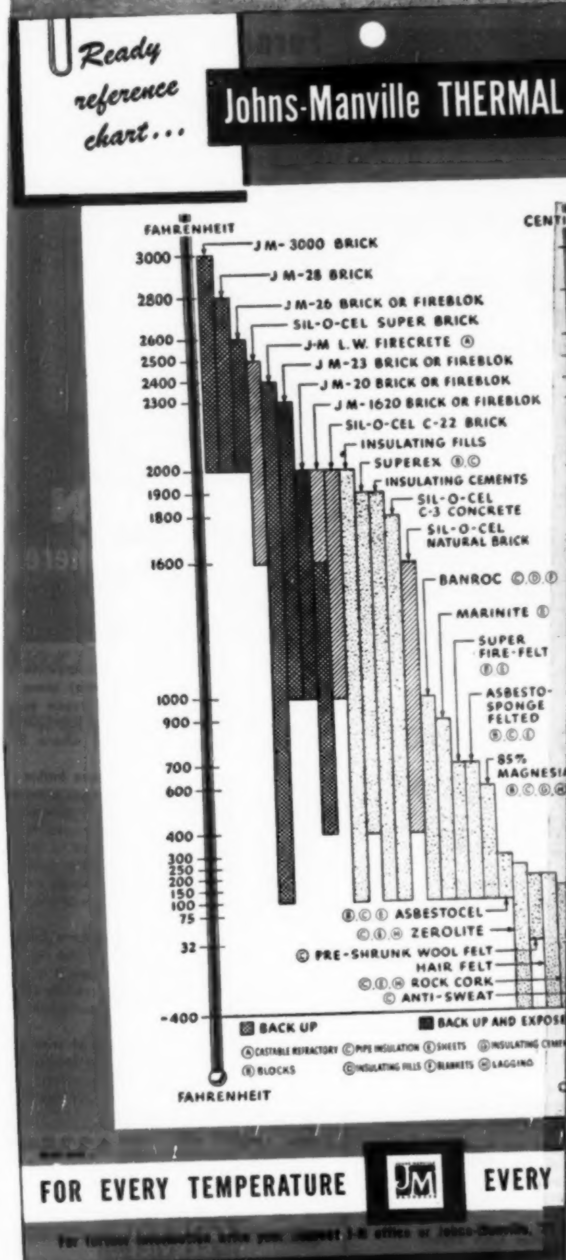
The curves for reduction in area at the root of the notch and for energy absorption per unit of root area are quite similar as to significant characteristics and a similar relationship exists between the curves for energy absorption per unit of area before and after fracture. It is indicated that this should be expected because of the nearly linear relation between the energy absorption per unit of root area and the reduction in area.

Transition temperatures based on reduction in area are within 5° F. of those based on absorbed energy. Transitions determined from energy absorption per unit of fracture area vary from 5° F. lower to 20° F. higher, but are generally slightly higher than those determined by energy absorption alone. Transitions based on a 15% reduction in area are generally 5 to 10° F. lower, and sometimes 15° F. lower, than those determined by energy absorption alone. It is indicated that, with an initial pendulum energy of 45 ft-lb., a fair agreement exists between the transitions determined here and those determined previously from the tests of specimens 72 in. wide.

The authors point out that the most consistent results are obtained from axial tension-impact tests when the specimen is notched in such a way that virtually all the energy must be absorbed in the region of the notch. Apparently the standard specimen developed for this program of testing fulfills this condition. Also, sharper and more definite transition regions are obtained at the lower values of initial energy.

One of the most interesting features of the test is the possibility of using reduction in area at the root section to determine the transition range. This means that simpler testing machines can be used, since

(Continued on p. 564)



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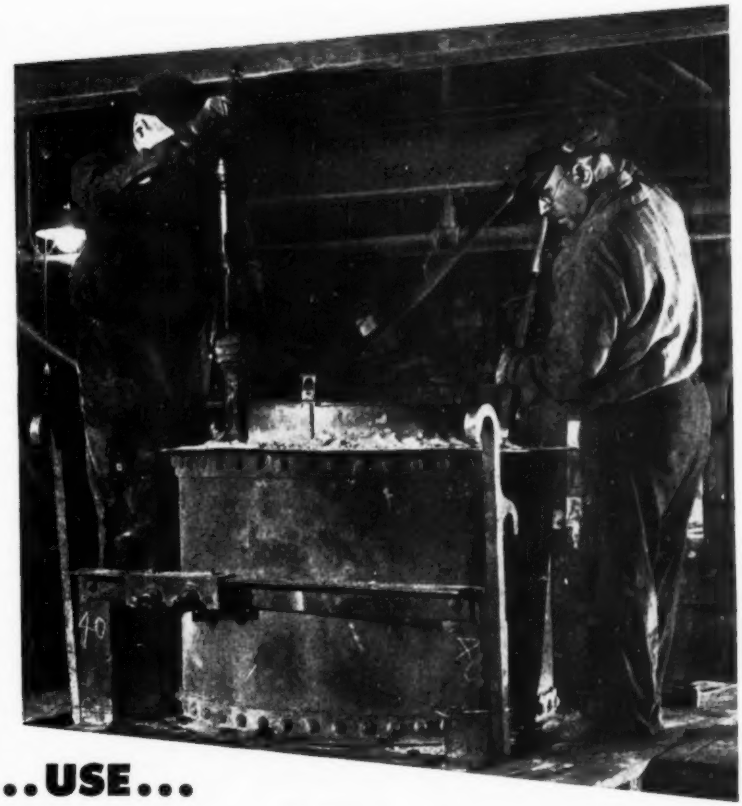

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TENSION-IMPACT OF SHIP STEELS

(Starts on p. 556)

only measurements of temperature and diameter would be required.

These observations might be considered to suggest the following tentative conclusions: *(a)* Since energy absorption depends on the volume of metal deformed plastically during the test, the more precisely the volume affected can be defined the more uniform will be the energy absorption from specimen to specimen; and *(b)* less scatter in energy absorption is produced by lowering strain rate in metals of high transition temperature.

Although the authors have not exhibited plots of type of fracture versus temperature, the tabulated data on percentage of shear fracture seem to suggest the following tentative conclusions: *(a)* Appreciable energy absorption occurs at temperatures below that at which complete cleavage fracture appears; and *(b)* as strain rate decreases, the temperature at which complete cleavage fracture appears is lowered.

WEAR*

THE FIRST PART of this book was written by F. P. Bundy, General Electric Co., and deals with theory and research. Equipment for testing sliding wear under constant and variable pressures is discussed in relation to the wear of cylinders and rings. In spite of careful control of all the obvious variables, the author observed sudden changes in the rate of wear and was forced to conclude that some of the important factors are difficult to control.

In the second part, T. E. Eagan, chief metallurgist, Cooper-Bessemer Corp., describes the service conditions and results obtained from attempts to evaluate the importance of variation in metallurgical factors on the wear of cylinder liners. From these service tests, which included engines running under varying load conditions, in marine service and with corrosive fuels, the author concludes that for liners: *(a)* The best microstructure is a random flake distribution of graphite in a pearlitic matrix; *(b)* copper, if not added with chromium and molybdenum, is detrimental to wear resistance; *(c)* cast irons containing 2.85 to 3.30% total C, 1.25 to 1.70% Si, 1.00% Mn max., 0.20% P max., 0.12% S max., 1.00 to 1.50% Ni, 0.30 to 0.40% Cr, and 0.25 to 0.35% Mo give the best combination of wear resistance and castability; and *(d)* hardening the liners from the normal 190 to 415 Brinell increases the wear resistance, but not enough to justify increased cost.

The book concludes with a discussion of the design aspects of cylinder and ring wear by Ralph L. Boyer, vice-president and chief engineer, Cooper-Bessemer Corp., who points out that better cooling of the top liner, better cooling of the ring itself and a narrower ring are the three major methods for reducing cylinder and ring wear.

The average metallurgist or the reader not familiar with this field may find it difficult to follow some of the concepts of rubbing intensity and wear factors, and to understand the diagrams in the last section. The book would be especially valuable to anyone who is considering setting up laboratory wear tests to simulate or interpret service results.

*Abstract of "Wear, as Applied Particularly to Cylinder and Piston Rings", Cooper-Bessemer Corp., 1948.

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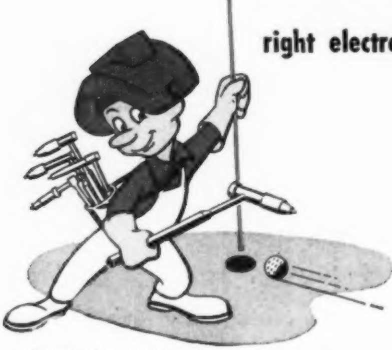

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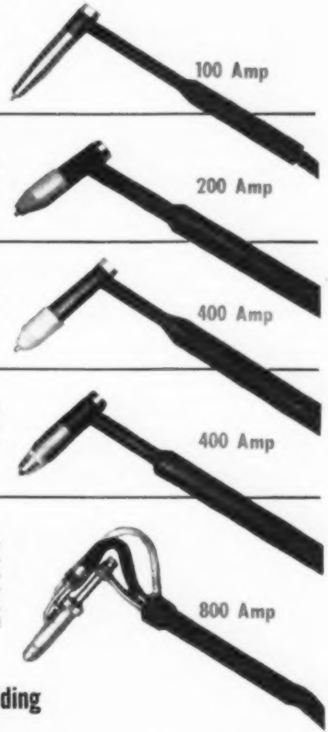

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400-amp holder with integral water-cooled metal nozzle. Tips of 2 orifice diameters are furnished.

800-amp holder furnished with one electrode assembly for each size listed and with 3 water-cooled metal nozzles, one for 5/16- and 3/8-in. electrodes, one for 1/16-in. electrodes, and one for 1/2-in. electrodes.

"Balanced-wave" Welding Doesn't "Broadcast"

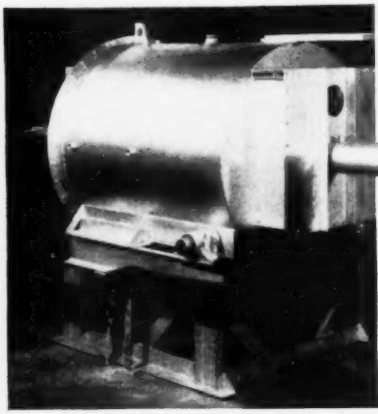
By using a high-frequency pilot for only 1/20th of a second while starting the arc, the General Electric WP Inert-Arc Welder eliminates continuous high-frequency radio signal. For more detailed information, see your local G-E Arc-welding Distributor, or write for Bulletins GEA-4930 and GEA-5146, Apparatus Dept., General Electric Co., Schenectady 5, N. Y.

Minimized radio interference is just one of the many "plus values" offered by G-E Inert-Arc welding transformers. They also provide:

A Clean Process • Economy of Current • Savings in Gas • Superior Weld Contour • Proper Penetration • Close Control of Filler Metal • Concentrated Source of Heat

GENERAL ELECTRIC

DESIGNERS and BUILDERS of SPECIAL HIGH TEMPERATURE ELECTRIC FURNACES



Harper Electric Special Carbon Tube Furnace for Sintering at High Temperatures

One of many Harper Furnaces designed for sintering metal powders in special atmospheres at high temperatures to 4500°F. It is equipped with 3″ Dia. Graphite Tubular Element. Materials are passed through entrance zone into a 13″ long uniform heating zone and out into a 22″ long water-cooled cooling chamber. Gas-tight construction permits use of special atmospheres inside the furnace shell and tubular element. Entrance and exit doors provided with flame seals for maintaining special atmospheres.

Write for information today on special designs for your high temperature firing needs.

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The Jaco Projection Comparator Microphotometer Offers:

1. Improved Resolution: Lines as narrow as 10-15 microns can be photometered.
2. Greater Certainty: The line can be observed as it is scanned.
3. A Wider Density Range: Lines can be photometered usefully to densities of 1.3 and higher.
4. Increased Comfort: The unknown spectrum, reference spectrum and galvanoscope scale are observed side by side at table level, as one would read a book.
5. High Speed: Controls are immediately at hand. An operator can readily photometer as many as 5 lines per minute.
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Brookhaven National Laboratory (2 instruments)
Geological Survey (3 instruments)
National Lead Company
Watervliet Arsenal
National Bureau of Standards (2 instruments)
Watertown Arsenal — M. I. T. Lab.
Indiana University
Dow Chemical Company
M. I. T. — Geology Department
Chance Vought Aircraft Corp.
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Ask for Catalogue I-4

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WHY EVERY METAL USER SHOULD...

Take a good look at

MAGNESIUM

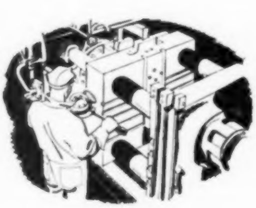
MAGNESIUM'S LIGHTNESS is vitally important to many users. But there are other significant facts that every metal consumer should know about magnesium.

First, magnesium is an excellent production material. It's a workable material. Magnesium ingot is readily fabricated—in most cases with the same equipment used for other metals—into die castings, sand castings, and permanent mold castings possessing excellent strength, stiffness, and durability.

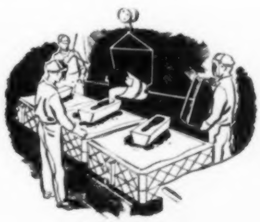
Second, magnesium ingot is readily available. Today's production facilities assure you of prompt delivery. More than that, magnesium is produced from sea water, insuring long range supply almost as inexhaustible as the sea itself.

Third, magnesium ingot is priced more favorably than ever before. While most other metal prices have been going up, the base price of magnesium has remained stable. In fact, by volume, magnesium ingot is one of the lowest priced structural metals today.

Take another "good look"! You'll find, as have numerous other manufacturers, that *it pays to use magnesium.*



Die Castings



Sand Castings

Permanent Mold Castings

Magnesium ingot is readily available and easily fabricated

MAGNESIUM DIVISION

THE DOW CHEMICAL COMPANY

MIDLAND, MICHIGAN

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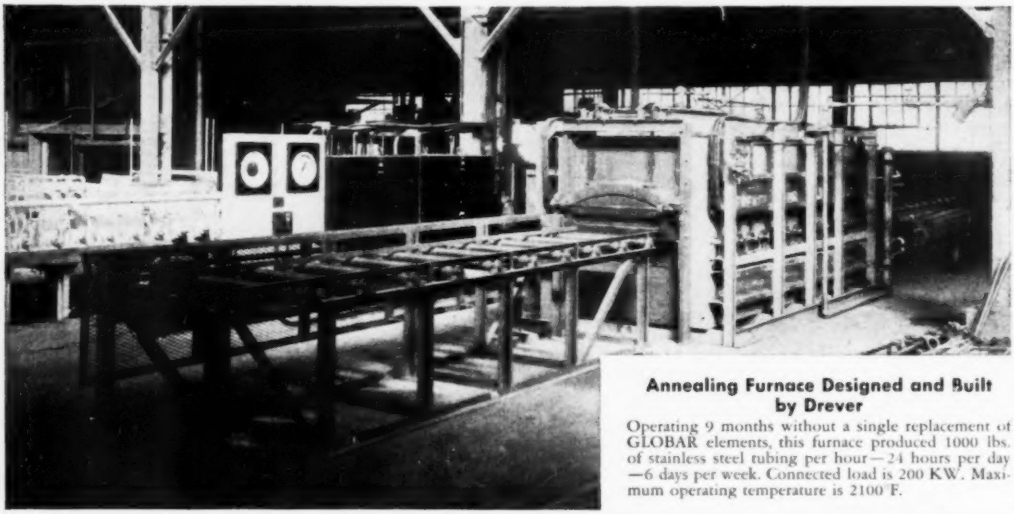
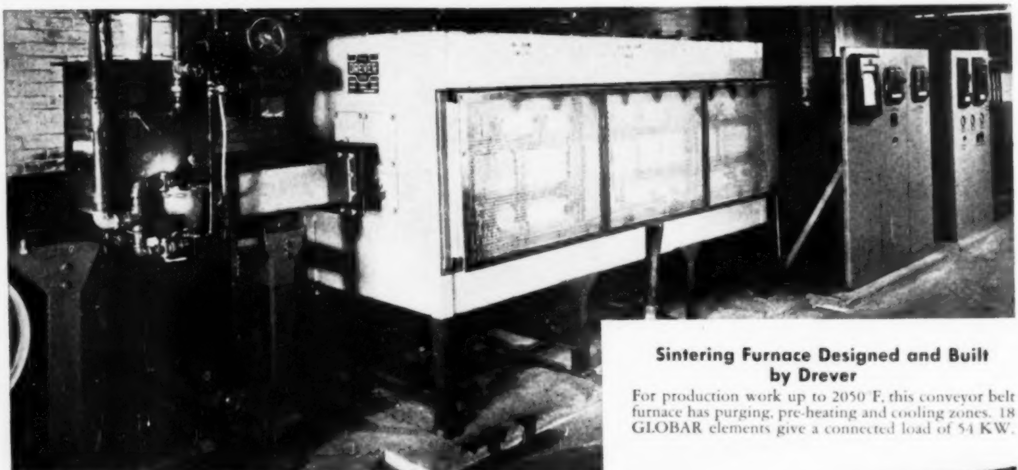
How heat treaters benefit



Annealing Furnace Designed and Built by Drever

Operating 9 months without a single replacement of GLOBAR elements, this furnace produced 1000 lbs. of stainless steel tubing per hour—24 hours per day—6 days per week. Connected load is 200 KW. Maximum operating temperature is 2100°F.

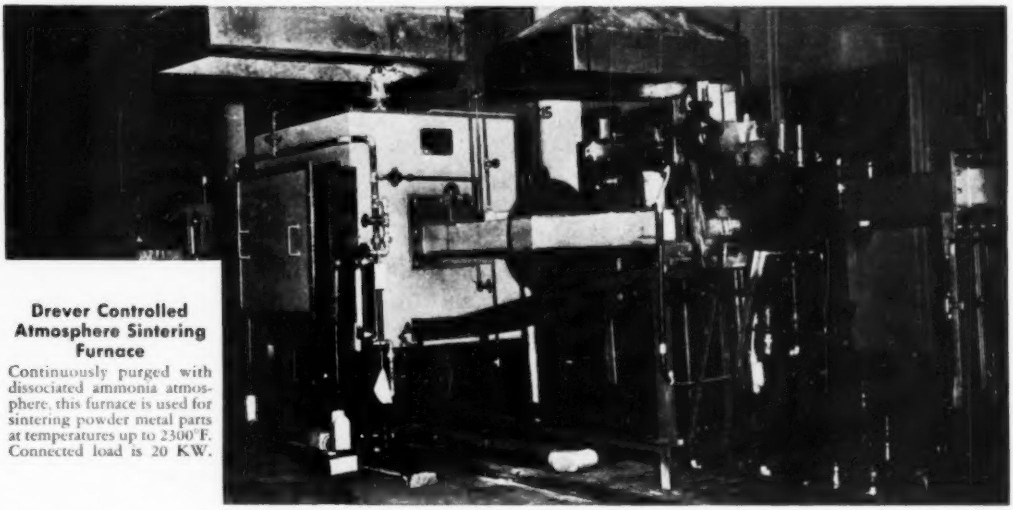


Sintering Furnace Designed and Built by Drever

For production work up to 2050°F, this conveyor belt furnace has purging, pre-heating and cooling zones. 18 GLOBAR elements give a connected load of 54 KW.

CARBORUNDUM

with ELECTRIC HEAT



Drever Controlled Atmosphere Sintering Furnace

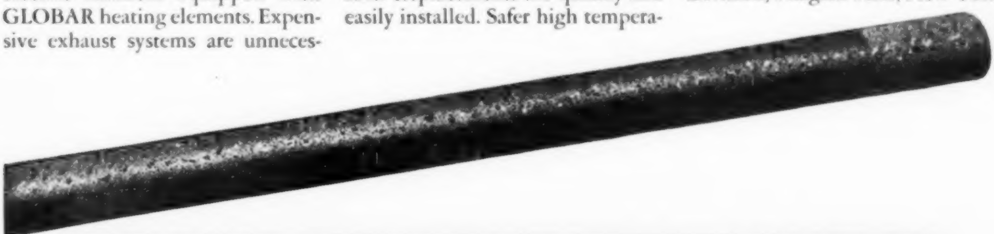
Continuously purged with dissociated ammonia atmosphere, this furnace is used for sintering powder metal parts at temperatures up to 2300°F. Connected load is 20 KW.

GLOBAR silicon carbide heating elements installed in properly engineered electric furnaces maintain uniform work chamber temperatures. This characteristic makes them especially desirable for handling many difficult heating assignments. It is an important reason why they can be depended upon to produce consistently excellent results.

Cleaner operation also characterizes electric furnaces equipped with GLOBAR heating elements. Expensive exhaust systems are unnecessary due to absence of dirt and fumes. Scale is eliminated. Time consuming cleaning operations are avoided. And since these elements burn very little oxygen out of the air, an oxidizing atmosphere is assured while a reducing atmosphere may be obtained under controlled conditions.

With GLOBAR elements, furnace maintenance is greatly simplified. Element service is long and dependable. Replacements are quickly and easily installed. Safer high temperature operation is realized through elimination of explosion and fire hazards.

Investigate the possibilities of electric heat in your operation. Our technical staff is at your disposal to aid you in seeking a solution to heating problems or analyzing present techniques. There is no obligation of course. Write Dept. X-49, The Carborundum Company, GLOBAR Division, Niagara Falls, New York.



GLOBAR Heating Elements
BY CARBORUNDUM
TRADE MARK

HI-TEMPERATURE TOOLING — ENGINEERED AND BUILT FOR THE JOB AS NEVER BEFORE!

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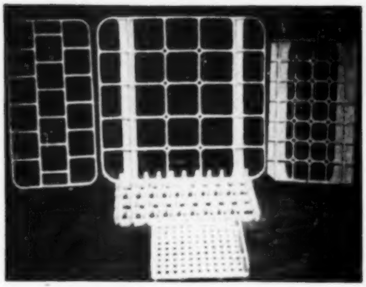
Better Planned — Better Tooled — Better Manned!



Continuous Furnace Trays

Carburizing Boxes

← *Carburizing Retorts*

WE MAKE A COMPLETE RANGE OF HEAT AND CORROSION RESISTANT CASTINGS

We have a standard line of highly developed heat treating equipment pressure cast from metal patterns which, if they are suited to your use, will render far better service than contemporary designs made by conventional foundry methods. These items include cyanide, lead and salt pots, carburizing retorts and boxes, trays, fixtures—trays for pusher furnaces—chain-hearth plates, etc. Nickel-chrome and chrome-alloy for all heat and corrosion resistant applications.

HEAT RESISTANT ALLOYS

Approximate Analysis

Name	Nickel	Chrome	Carbon (nominal)
Accoloy NC-1*	68%	18%	As Required
Accoloy NC-2	60%	12%	" "
Accoloy NC-3*	38%	18%	" "
Accoloy NC-4	35%	15%	" "
Accoloy NC-5	30%	10%	" "

Name	Chrome	Nickel	Carbon (nominal)
Accoloy CN-1	28%	3% Max.	.20%
Accoloy CN-2	28%	10%	.40%
Accoloy CN-3	25%	20%	.30%
Accoloy CN-4	25%	12%	.35%
Accoloy CN-5	18%	8%	.25%

**Top quality alloys recommended for maximum service at minimum overall cost. Each is definitely a much better value at slightly higher cost than the alloy immediately below it.*

CORROSION RESISTANT ALLOYS

Approximate Analysis

Name	Chrome	Nickel	Carbon
Accoloy CNC-4D	24%	12%	.20% max.
Accoloy CNC-4B	24%	12%	.10% max.
Accoloy CNC-5C	18%	8%	.16% max.
Accoloy CNC-5B	18%	8%	.10% max.
Accoloy CNC-5A	18%	8%	.07% max.

All of the corrosion resistant alloys can be supplied with .30% Selenium for machining qualities; with Columbium or Titanium for carbide stabilization and with 1½% Molybdenum for special anti-corrosive properties. Molybdenum may be increased to 3% in some grades.

The Heat Resistant analyses are made with a variety of secondary alloying elements, manganese, silicon, molybdenum, titanium, tungsten, copper, aluminum, etc., for special purposes.

This is a partial list of the alloys we are most currently producing. We make many others.

ACC

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Champaign, Illinois

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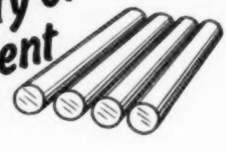
Speed

\+ Economy

\+ Uniformity of Treatment



with Du Pont

ACCELERATED SALT WS

The Free-Washing Liquid Carburizer

ONE BATH FOR CYANIDING AND LIQUID CARBURIZING

Check these 9 outstanding Advantages

1. **Free washing**—The salts composing this bath and their decomposition products are completely water soluble. Even detergents that may be used in cleaning oil-quenched work do not precipitate water insolubles with Du Pont Accelerated Salt WS.

2. **Excellent carburizing activity**—over a wide operating temperature range (1500°—1650°F.).

3. **Bail-out eliminated**—The high cyanide content of Accelerated Salt WS (66% NaCN, minimum) will maintain the average bath at operating strength by simply diminishing drag-out losses.

4. **Excellent fluidity**—A minimum of salt dragged out on the treated work.

5. **Low molten density**—Less salt for the initial charge and reduced fresh salt replenishments as compared to the barium-activated salt baths.

6. **Minimum heat radiation losses and fuming**—with the floating graphite cover. For the convenience of the operator, graphite is incorporated into the Du Pont Accelerated Salt WS mixture.

7. **Easy-to-handle pellets**—uniformly sized weighing approximately one ounce. A minimum of dust to annoy the operators when making bath replenishment additions.

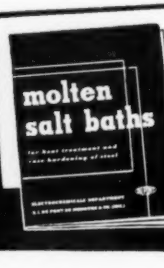
8. **No sludge formation**—from infusible salt residues. All salts in the Du Pont Accelerated Salt WS mixture and their decomposition products form an homogenous melt at operating temperature.

9. **Simple bath control**—A single replenishment will maintain activity for at least twenty-four hours at operating temperature. Cyanide analysis, which is rapid and simple, is the only chemical control required.

For further information on Du Pont Accelerated Salt WS, or for experienced advice and technical assistance in selection and application of Du Pont heat treating materials, write or call our nearest district office. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

DISTRICT OFFICES: Baltimore, Boston, Charlotte, Chicago, Cincinnati, Cleveland, Detroit, El Monte (Calif.), New York, Philadelphia, Pittsburgh, San Francisco.

Tune in to Du Pont "Cavalcade of America" Monday nights—NBC Coast to Coast



FREE MANUAL ON MOLTEN SALT BATHS

More than 70 pages of practical material on heat treatment, fully illustrated. Ask for your copy.

DU PONT

DU PONT CYANIDES and SALTS

for Steel Treating

BETTER THINGS FOR BETTER LIVING ... THROUGH CHEMISTRY

MOORE JIG BORER built with MEEHANITE® CASTINGS for...

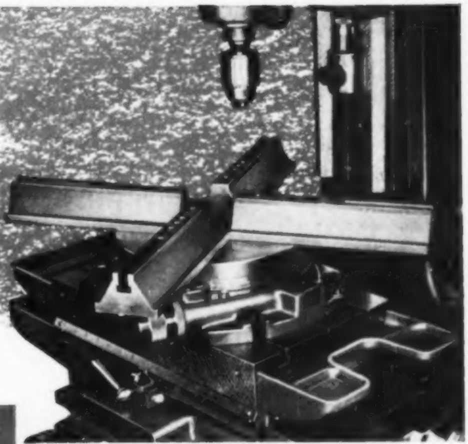


Fig. 2. Typical set-up of Meehanite extension parallels.

"Control of Hardness"

"Uniform Grain"

"High Strength"

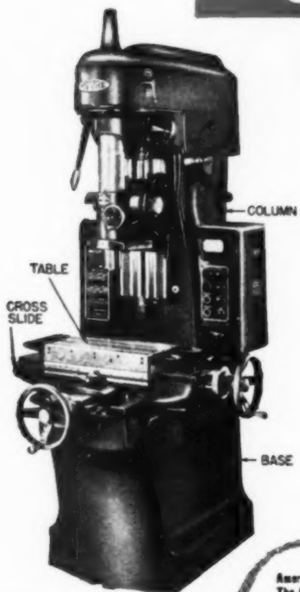


Fig. 1. Important Meehanite castings used in the construction of the Moore No. 2 Jig Borer.

The precision jig borer illustrated (Fig. 1), manufactured by the Moore Special Tool Co., Inc., Bridgeport, Connecticut, uses Meehanite castings extensively because of their contribution to the quality, accuracy and precision operation of this machine tool.

The important castings indicated are, according to the chief engineer of the company, specified as Meehanite castings for the following reasons:

1. "Close control of hardness for maximum wear resistance, yet just within the range of hand scraping."
2. "Uniform close grain for good machinability and absence of blow holes."
3. "High tensile strength and resistance to deflection."

In addition a number of fixtures similar to the extension parallels (Fig. 2) are Meehanite castings for similar reasons.

Complete machining data for various types of Meehanite castings is tabulated and illustrated in our new Bulletin No. 29 "How to Machine Meehanite Castings." For a copy write to any of the foundries listed.

MEEHANITE FOUNDRIES

American Brake Shoe Co.	Mahwah, New Jersey	Koehring Co.	Milwaukee, Wisconsin
The American Laundry Machinery Co.	Rochester, New York	Lincoln Foundry Corp.	Los Angeles, California
Atlas Foundry Co.	Detroit, Michigan	The Henry Perkins Co	Bridgewater, Massachusetts
Banner Iron Works	St. Louis, Missouri	Pohlman Foundry Co., Inc.	Buffalo, New York
Barnett Foundry & Machine Co.	Irvington, New Jersey	Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
H. W. Butterworth & Sons Co.	Bethayres, Pennsylvania	Ross-Meehan Foundries	Chattanooga, Tennessee
Continental Gin Co.	Birmingham, Alabama	Shenango-Penn Mold Co.	Dover, Ohio
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.	Sonith Industries, Inc.	Indianapolis, Indiana
Crawford & Doherty Foundry Co.	Portland, Oregon	Standard Foundry Co.	Worcester, Massachusetts
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut	The Stearns-Roger Manufacturing Co.	Denver, Colorado
Florence Pipe Foundry & Machine Co.	Florence, New Jersey	Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio	U. S. Challenge Co.	Centerville, Iowa and Batavia, Illinois
General Foundry & Manufacturing Co.	Flint, Michigan	Valley Iron Works, Inc.	St. Paul, Minnesota
Greenlee Foundry Co.	Chicago, Illinois	Vulcan Foundry Co.	Oakland, California
The Hamilton Foundry & Machine Co.	Hamilton, Ohio	Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey
Johnstone Foundries, Inc.	Grove City, Pennsylvania	E. Long Ltd.	Orillia, Ontario
Kanawha Manufacturing Co.	Charleston, West Virginia	Otis-Fensom Elevator Co., Ltd.	Hamilton, Ontario

"This advertisement sponsored by foundries listed above."

Meehanite® NEW ROCHELLE, N. Y.

OALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION **X-ite**

La Jolla (La Hoy-ya), Califony, subject of Author Max ("I Cover Waterfront") Miller's last and feebler book, "The Town with the Funny Name", has warmed our cockles and bent our checkbook thru February. (We ducked all responsibility — even M.P. George Loughner wrote our last month's M.P. "Copy". It looked more like an "ad". Thanks, George!) La Jolla is a beautiful seashore dead-end where old folks go to visit their parents. It has a fine "Average" climate, but is essentially a Summer resort for financially eugenic Refugees from the cow & cactus country. It's one of the best spots in California, but don't kid yourself that Cal. is a Winter-Resort.

Over at Palm Springs, where horses die laughing at Humans, — you get sun, sand and heterogeniology, —but even the snakes and birds move out from May to December. Swank, in spots, there are good ones, like Rancho La Quinta, and a few clubs. "The Atlantic City crowd with more flash and less clothes on".

We were getting *too fat, too bald, too fast*. When the babes start calling you "Pop", it's time to fan that *last* spark, if you can *find* one. We want to pass our half-century mark with enough steam in the old boiler to blow the whistle, — so we went for an over-due check-up to the Scripps Metabolic Clinic at La Jolla. Friends who've toured the Clinic Circuit say these folks have high Competence and Sincerity, and no "larceny" in their souls, that a "patient" has full access to his records at all times, is not a guinea-pig in a net of "Professional" apcray.

The Scripps Clinic is endowed, it doesn't "Sell" anything, but it breaks even despite lower charges than average for even the bush-league hospitals. There is nothing a Doctor can do to you for a personal profit. There is, therefore, but one objective, to improve the health and life expectancy of us who come to seek their aid.

Dr. James W. Sherrill, who directs Scripps Clinic, is, basically, a Philosopher, as is Miss Helen B. Anderson, who heads Diatetics. The Staff is unexcelled in Professional experience, in fundamental scholarship, and in Human Understanding. "Loyalty to the Vision of Work Well Done" has built an ORGANIZATION high in Loyalty, Mentality and Vitality, whose Fine Morale is no product of propaganda, or smug mutual admiration, but of an individual and collective Sincerity of Purpose.

Fred Libby, once assistant to Donald Nelson, W.P.B. (remember the Libby Report on Steel?), renounced swivel chairs for Naval action, — liked seafaring, left Navy to become Chief Engineer of Tuna Fisherman "Sun Padre" out of San Diego. Net "share" for seven weeks' fishing, $3300.00 plus.

Bill Morse, who built Morse Tool and other Detroit Companies, now lives in La Jolla, is building three houses to sell Eastern Suckers, and running his Lincoln Continental on bottled gas. We left a new electric ice box, built into our Cadillac, for Bill to test. First test report: "Box keeps twelve bottles Wurtzberger three days on Desert on one battery charge". *Bill, or anybody else*, who can keep cold beer for *three days on a Desert*, has slipped from Detroit A.S.M. Standards. (Bob McCleary please note.)

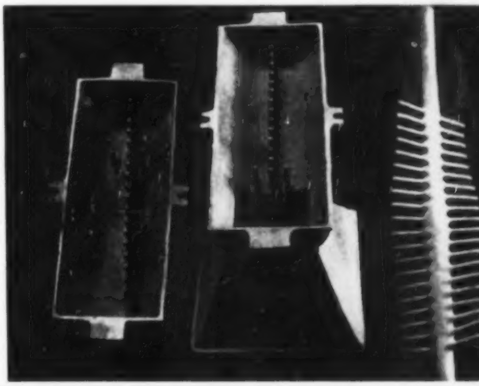
The Sunshine of California has not often compared with the "Sunshine of France" from bottles labeled "Sauterne", "Barsac", "Graves", or even "Vin Ordinaire". John Hamelet, ex-Commander in the French Navy, now an Engineer at Convair, has searched America for wine to his cultivated French Taste. His excellent judgment is: "Wente Brothers, Vintners, at Livermore, Cal., have cultivated their Sauvignon grapes since 1870. They don't spoil them by irrigation. Their 'Sauvignon' is a truly fine Sauterne". Check-and-double-check (and only buck-twenty-five a fifth). "21 Brands" is Eastern Distributor, ask your dealer.

W. K. (Kornflakes) Kellogg, Jr., operates the Kellogg Estate-owned La Jolla Beach & Tennis Club, hosting with a gracious informality that highly personalizes one of the most unique and attractive private club developments anywhere. Nowhere else have we dined with Ocean waves breaking against inch-thick-ply-glass windows.

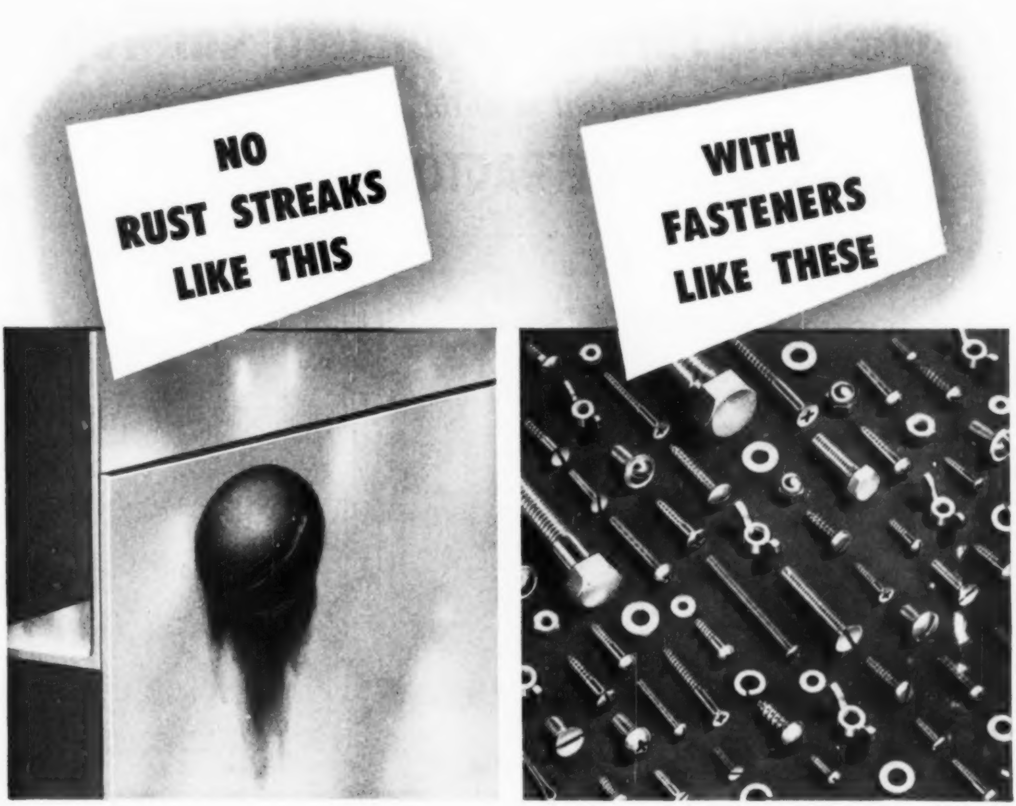
It seems we introduced Dr. Land's Polaroid Camera to California. (It takes, develops and prints a strikingly improved photograph in one minute.) This is a SENSATIONAL development! Equally new and *technically advanced*, if less spectacular, are the alloy casting developments in-the-making at General Alloys. In the industrial competition ahead, few plants can afford to buy "Cheap" alloy on the basis of low *first* cost. Heat Treating Departments are again keeping careful RECORDS of alloy life. Such records reveal THE MEASURABLE SAVINGS of G.A. products in relation to ALL other alloys tested, AND PARTICULARLY GREAT SAVINGS IN ULTIMATE COST AS COMPARED TO THE "BARGAIN" ALLOYS. VALUES can only be MEASURED by the SERVICE DELIVERED per Dollar COST. G.A. products are ENGINEERED to EXCEL by such standards. GENERAL ALLOYS WILL WELCOME YOUR INQUIRY.

An advertisement of General Alloys Company, Boston, Mass.

Consolidated Aircraft Co's. new XC99, "world's largest land plane", over Scripps Matabolic Clinic (Top Photo). Califony Alligator on our pillow at Clinic. Bambi makes a friend. "Sun Padre", Fred Libby's Tuna Boat. Yes, G.A. makes Heat & Corrosion Resistant Castings (Below).



THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY



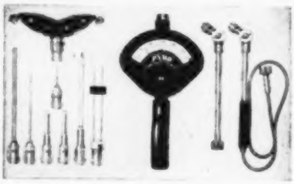
Alcoa Aluminum Fasteners offer you corrosion resistance at lowest cost

Alcoa Fasteners are corrosion resistant all the way through—won't ever red rust-streak your aluminum assemblies. Made of tough aluminum alloy, they pull up into a strong, tight joint.

Alcoa Fasteners are available from stock with Phillips or slotted heads: in sheet metal, wood and machine screws; standard threads in all popular sizes and head types; nuts, bolts, washers, lock washers, solid or tubular rivets and cotter pins also available.

Investigate the low cost and sales advantages Alcoa Fasteners can give you! Write today, on your letterhead, for free samples to Aluminum Company of America, 2101 Gulf Bldg., Pittsburgh 19, Penna. Please specify types and sizes.

ALCOA *Aluminum* FASTENERS




CARL-MAYER
FURNACES
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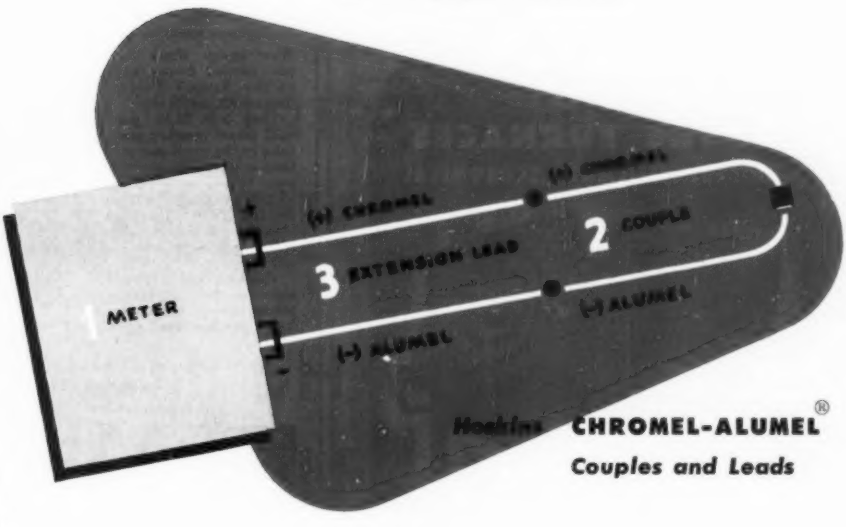
Right Combination for ACCURATE TEMPERATURE MEASUREMENT



Hoskins **CHROMEL-ALUMEL®**
Couples and Leads

If you're concerned with accurate temperature measurement in your heat treating operations, you'll do well to check your meter installations against the diagram shown above. It means simply this:

(1) Make sure your pyrometers are of recent manufacture . . . precision built . . . capable of accurately registering true temperature—EMF values . . . and calibrated for dependably accurate Chromel-Alumel Thermocouples.

(2) Standardize on durable Chromel-Alumel Thermocouples. They're highly responsive to temperature fluctuations . . . so resistant to oxidation you need not pack the protection tube. And they carry a positive accuracy guarantee of ± 5°F. from 32° to 660°F., and ± ¾% at temperatures above 660°F.

(3) Then, of course, complete your chain of accuracy by using Chromel-Alumel "extension" leads. For, by using wires of identical compositions for both couples and leads, you eliminate all possibility of "cold-end" errors.

Our Catalog M[1] tells the complete technical story . . . and additional reference can be found in the following Bureau of Standards Research papers: R.P. 767—"Standard Tables for Chromel-Alumel Thermocouples"; R.P. 768—"Methods of Testing Thermocouples"; R.P. 1278—"Stability of Base Metal Thermocouples in Air at 800° to 2200°F."

Chromel-Alumel couples and leads are available through your pyrometer manufacturer.

HOSKINS MANUFACTURING COMPANY
4445 LAWTON AVE. • DETROIT 8, MICHIGAN

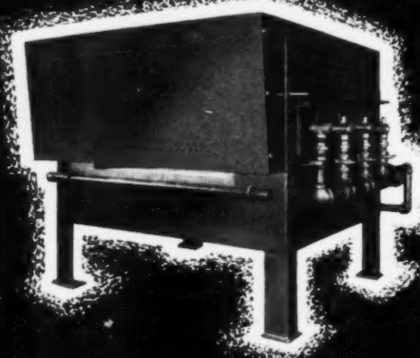
Heating Element Alloys ★ Heat Resistant Alloys ★ Thermocouple Alloys ★ Spark Plug Electrode Wire ★ Special Alloys of Nickel ★ Electric Heat Treating and Laboratory Furnaces

Performance Proves . . .

ECLIPSE

GAS-FIRED FORGE FURNACES

RUGGED . . . EFFICIENT . . . ECONOMICAL



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- HIGH GRADE FIREBRICK AND INSULATING FIREBRICK
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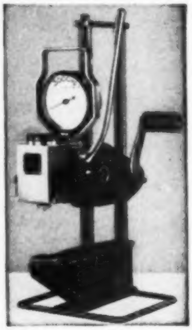

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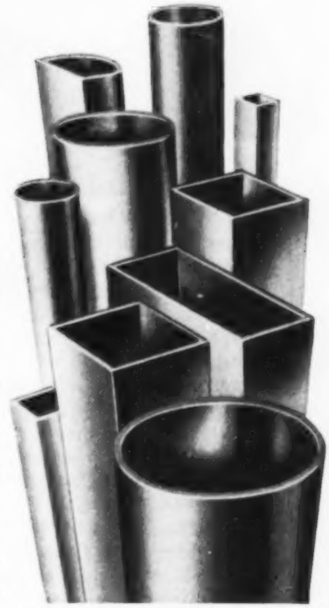

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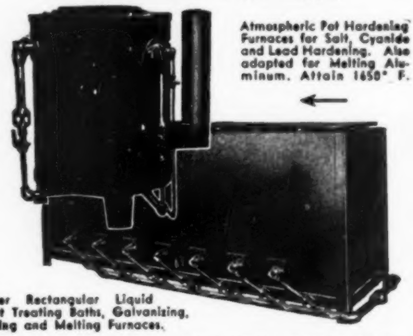

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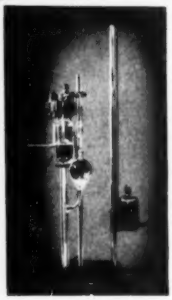

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PUBLISHED BY AMERICAN SOCIETY FOR METALS, 7301 EUCLID AVE., CLEVELAND 3, OHIO—W. H. EISENMAN, SECRETARY

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